US010837885B2

(12) **United States Patent**
Shavit et al.

(10) **Patent No.: US 10,837,885 B2**
(45) **Date of Patent: Nov. 17, 2020**

(54) THAWING BIOLOGICAL SUBSTANCES

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(73) Assignee: **FreMon Scientific, Inc.**, La Jolla, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/405,966**

(22) Filed: **May 7, 2019**

(65) **Prior Publication Data**

US 2019/0342946 A1 Nov. 7, 2019

Related U.S. Application Data

(60) Provisional application No. 62/668,034, filed on May 7, 2018.

(51) **Int. Cl.**

H05B 1/02	(2006.01)
G01N 1/44	(2006.01)
H05B 3/06	(2006.01)
A61M 1/02	(2006.01)
A61J 1/10	(2006.01)
A61J 1/16	(2006.01)
A01N 1/02	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***G01N 1/44*** (2013.01); ***A01N 1/0263*** (2013.01); ***A61J 1/10*** (2013.01); ***A61J 1/16*** (2013.01); ***A61J 1/18*** (2013.01); ***A61M 1/0281*** (2013.01); ***A61M 5/445*** (2013.01); ***B01F 11/0017*** (2013.01); ***B01F 15/065*** (2013.01); ***H05B 1/025*** (2013.01); ***H05B 3/06*** (2013.01); *A61J 2200/42* (2013.01); *A61J 2200/70* (2013.01); *A61J 2200/72* (2013.01); *A61J 2200/74* (2013.01); *A61J 2205/60* (2013.01); *A61M 1/025* (2013.01); *A61M 2205/3368* (2013.01); *A61M 2205/3393* (2013.01); *A61M 2205/36* (2013.01); *A61M 2205/3653* (2013.01); *A61M 2205/50* (2013.01); *B01F 2015/062* (2013.01); *B01F 2215/0034* (2013.01)

(58) **Field of Classification Search**

CPC H05B 1/02
USPC 366/145, 146, 149
See application file for complete search history.

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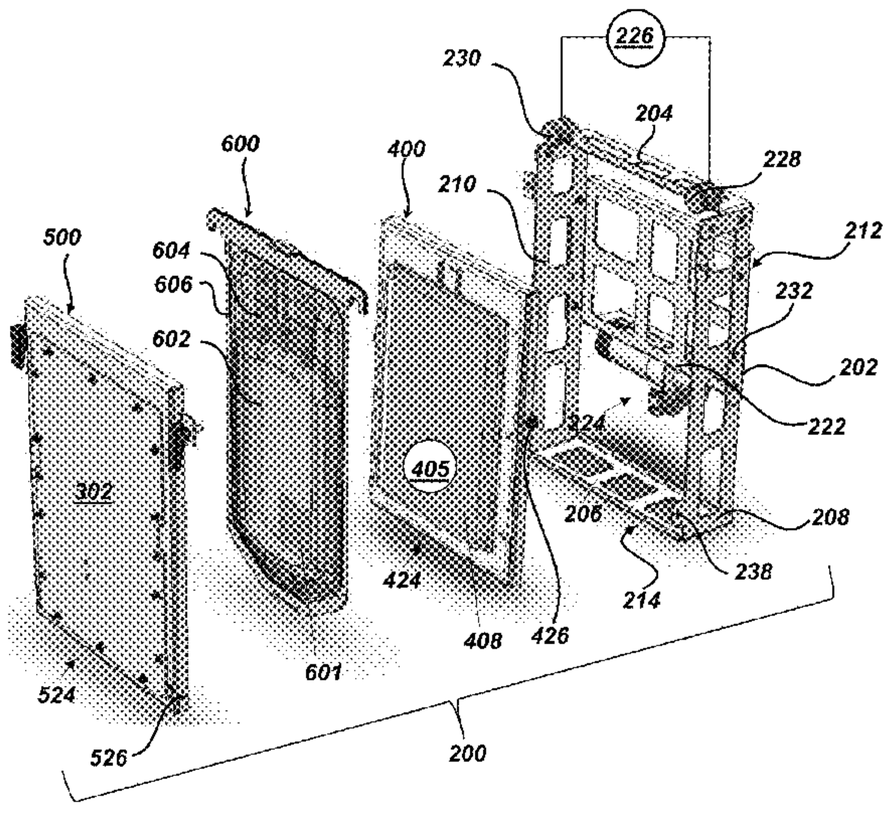
(74) *Attorney, Agent, or Firm* — Cooley LLP

(57) **ABSTRACT**

Dry thawing systems and devices for thawing biological substances are provided herein. Methods for thawing biological substances are also provided.

33 Claims, 40 Drawing Sheets



(51) **Int. Cl.**

A61J 1/18	(2006.01)
A61M 5/44	(2006.01)
B01F 11/00	(2006.01)
B01F 15/06	(2006.01)

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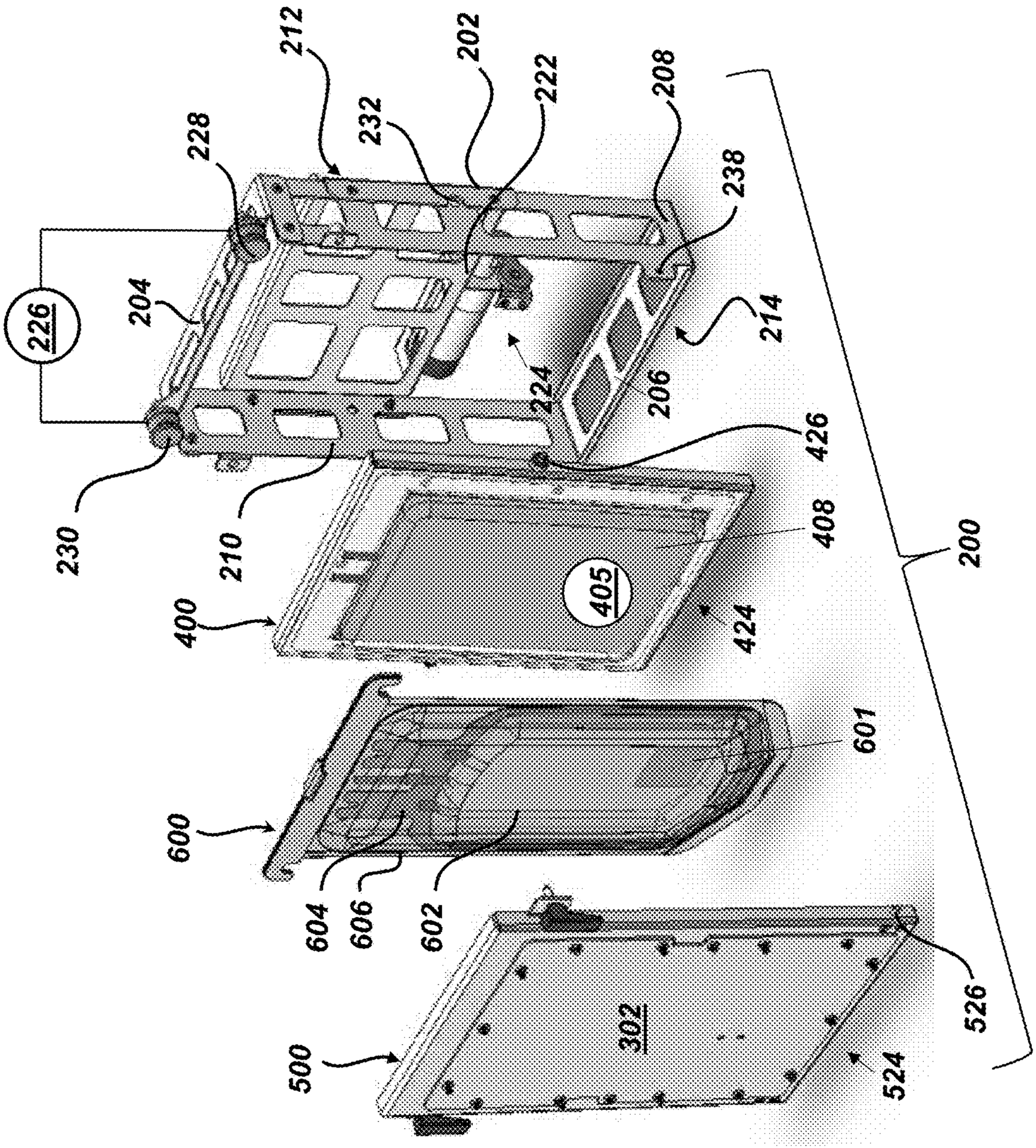
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FIG. 1A

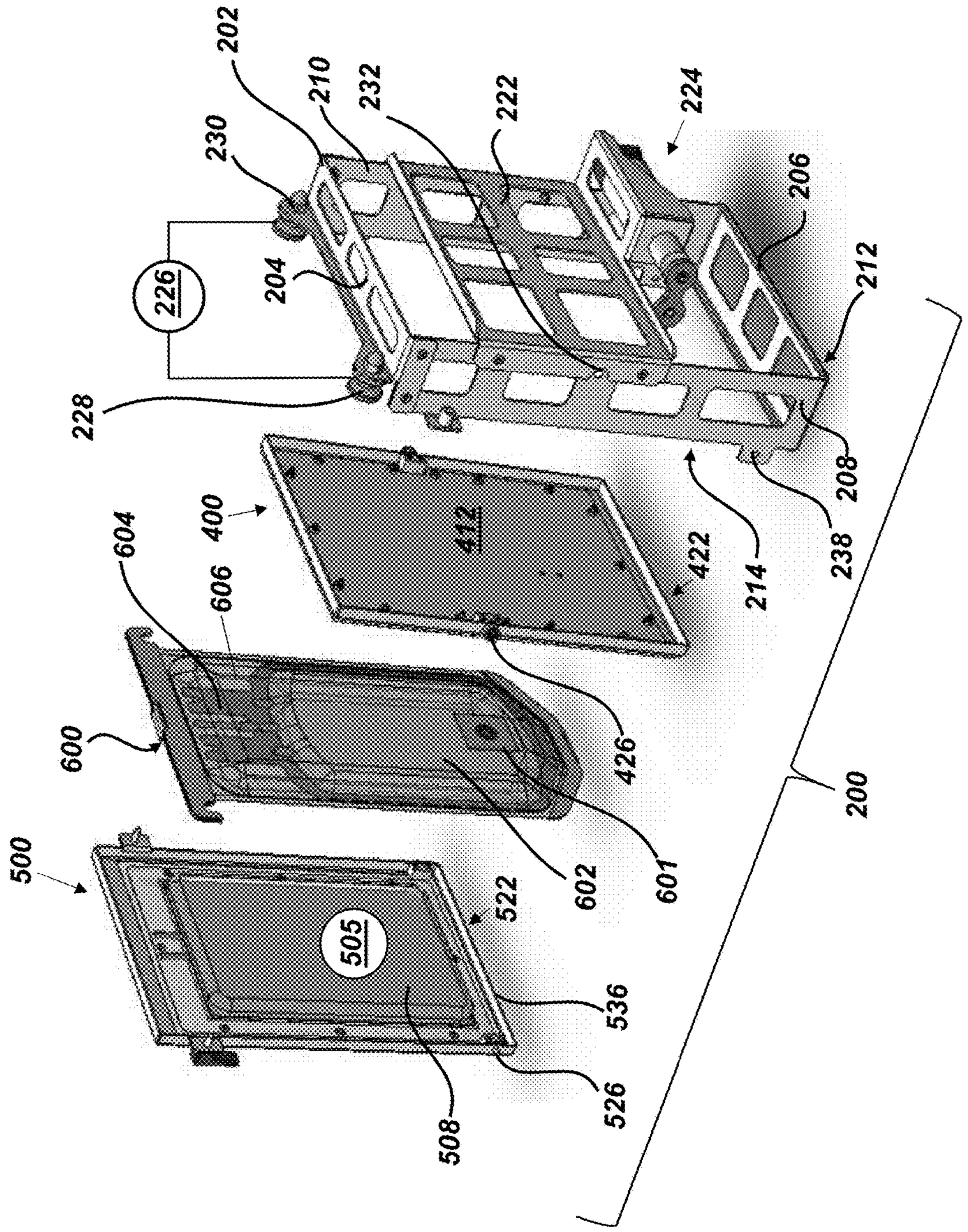
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FIG. 1B

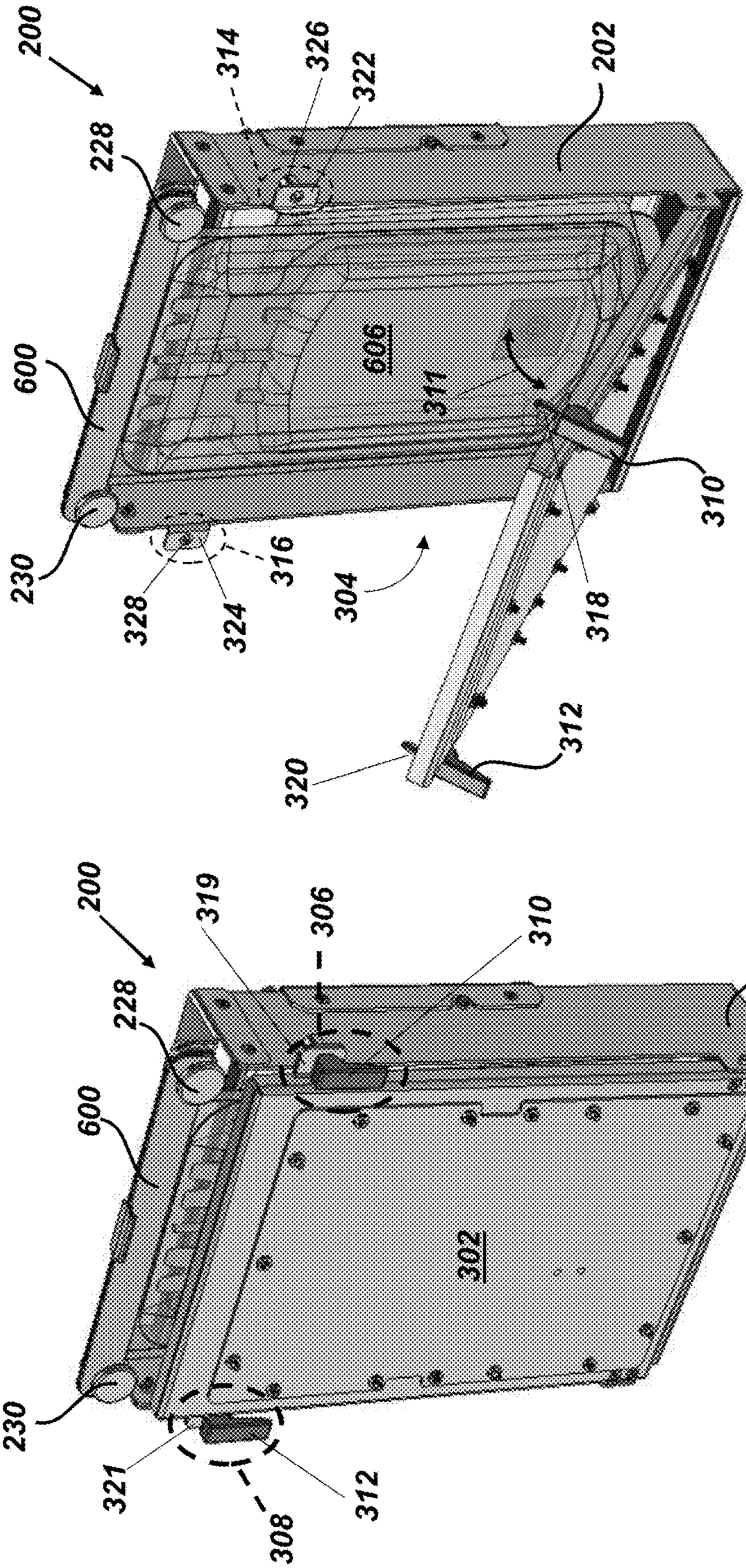
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FIG. 2B

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FIG. 2A

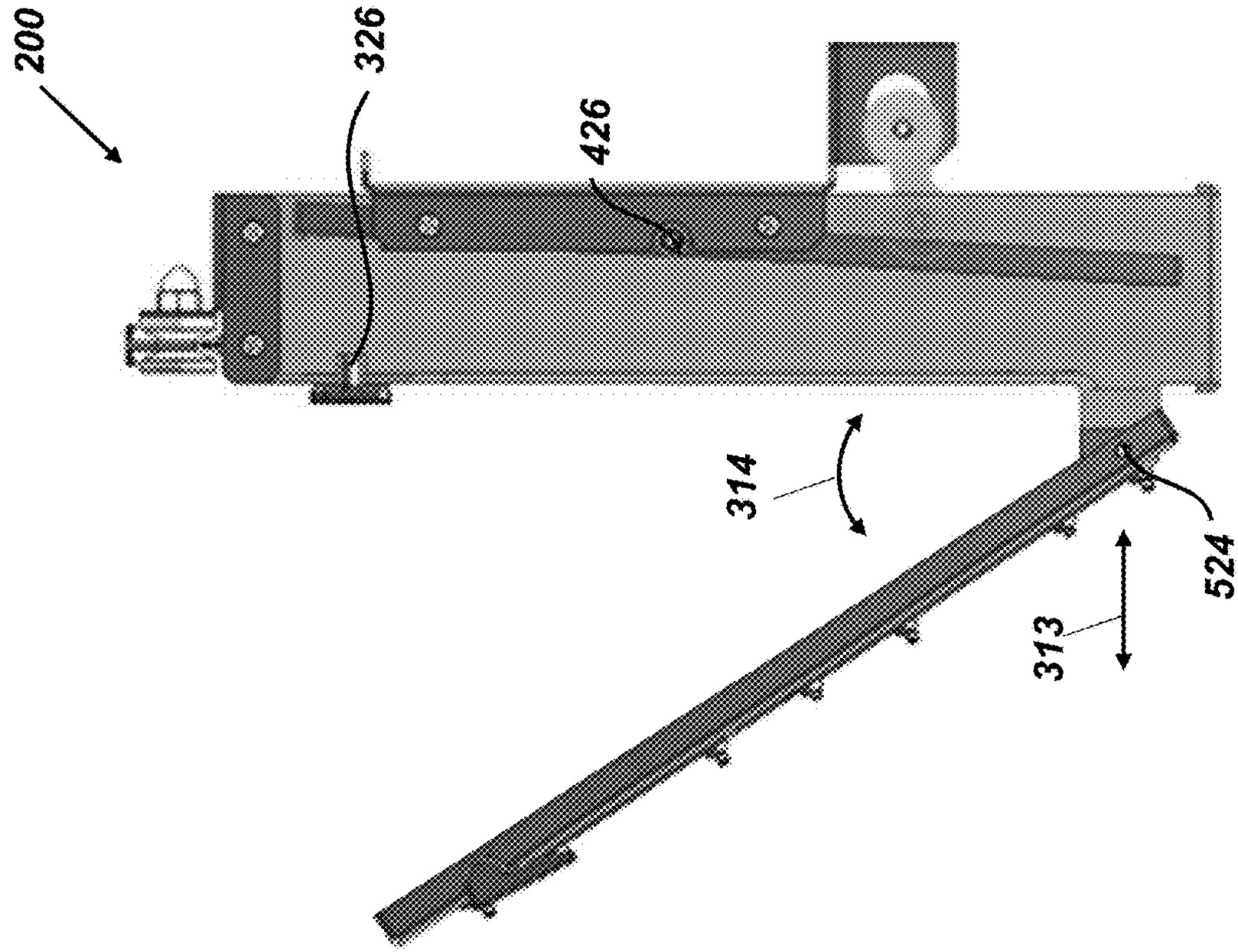


FIG. 2D

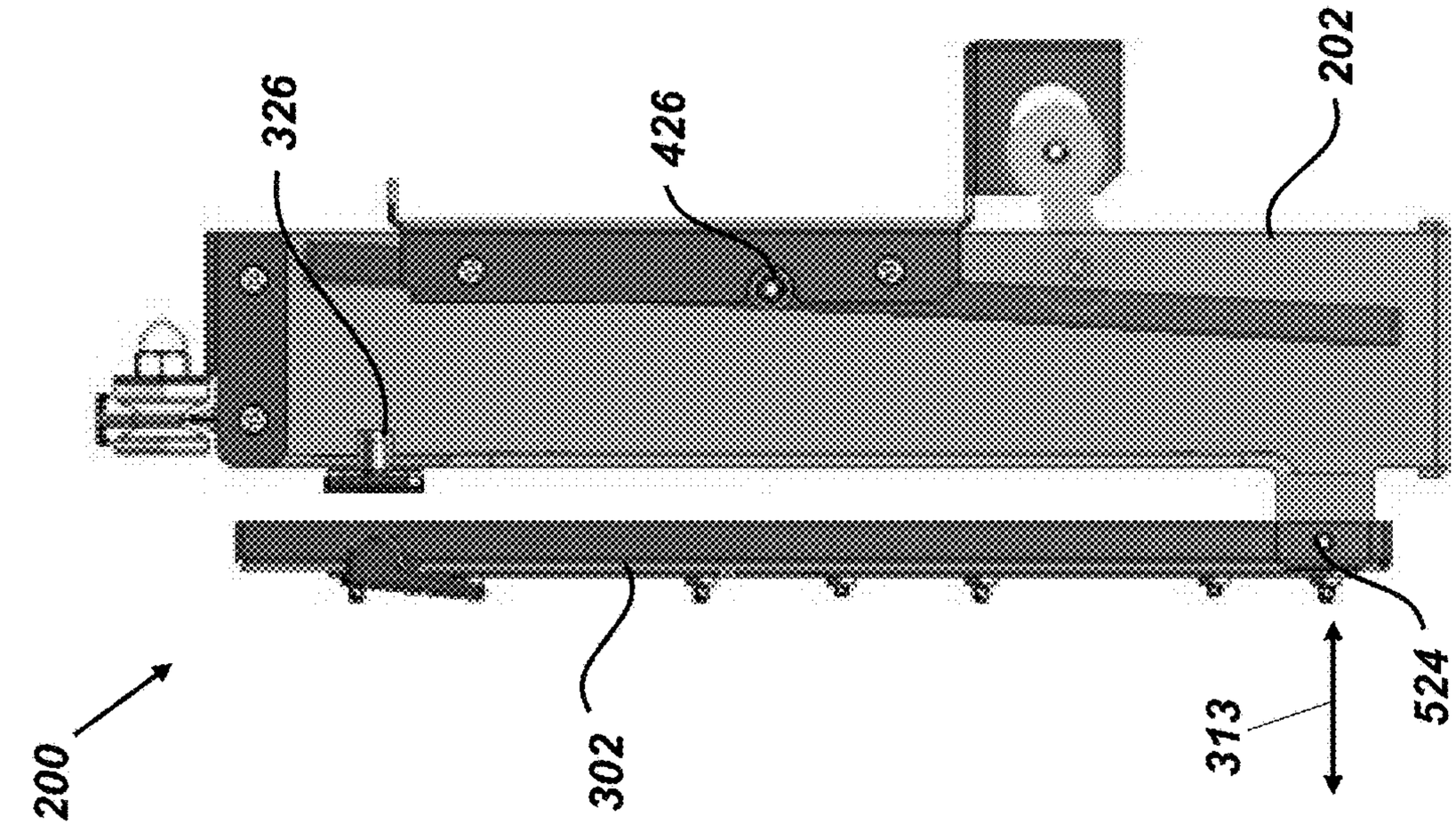


FIG. 2C

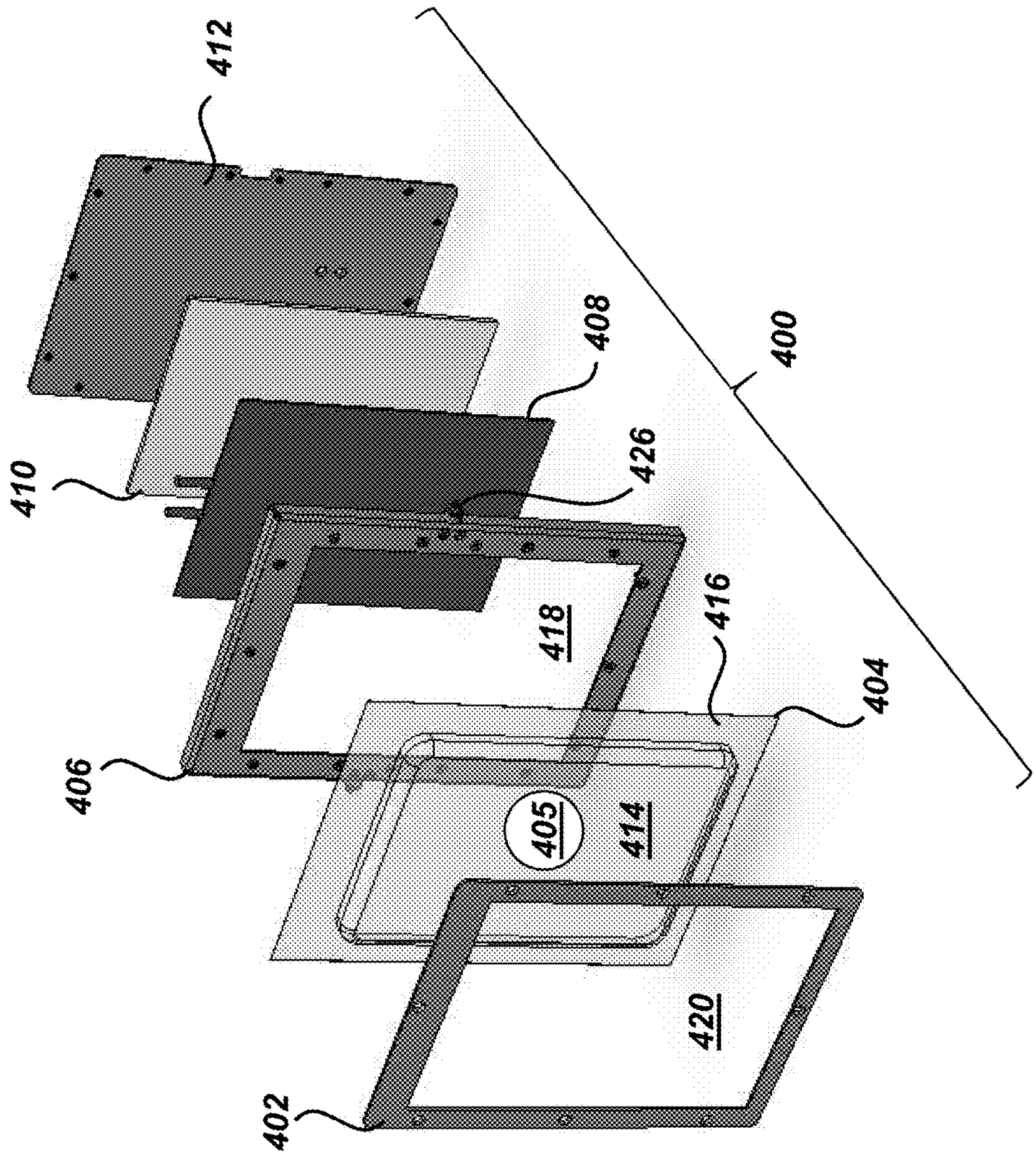


FIG. 3

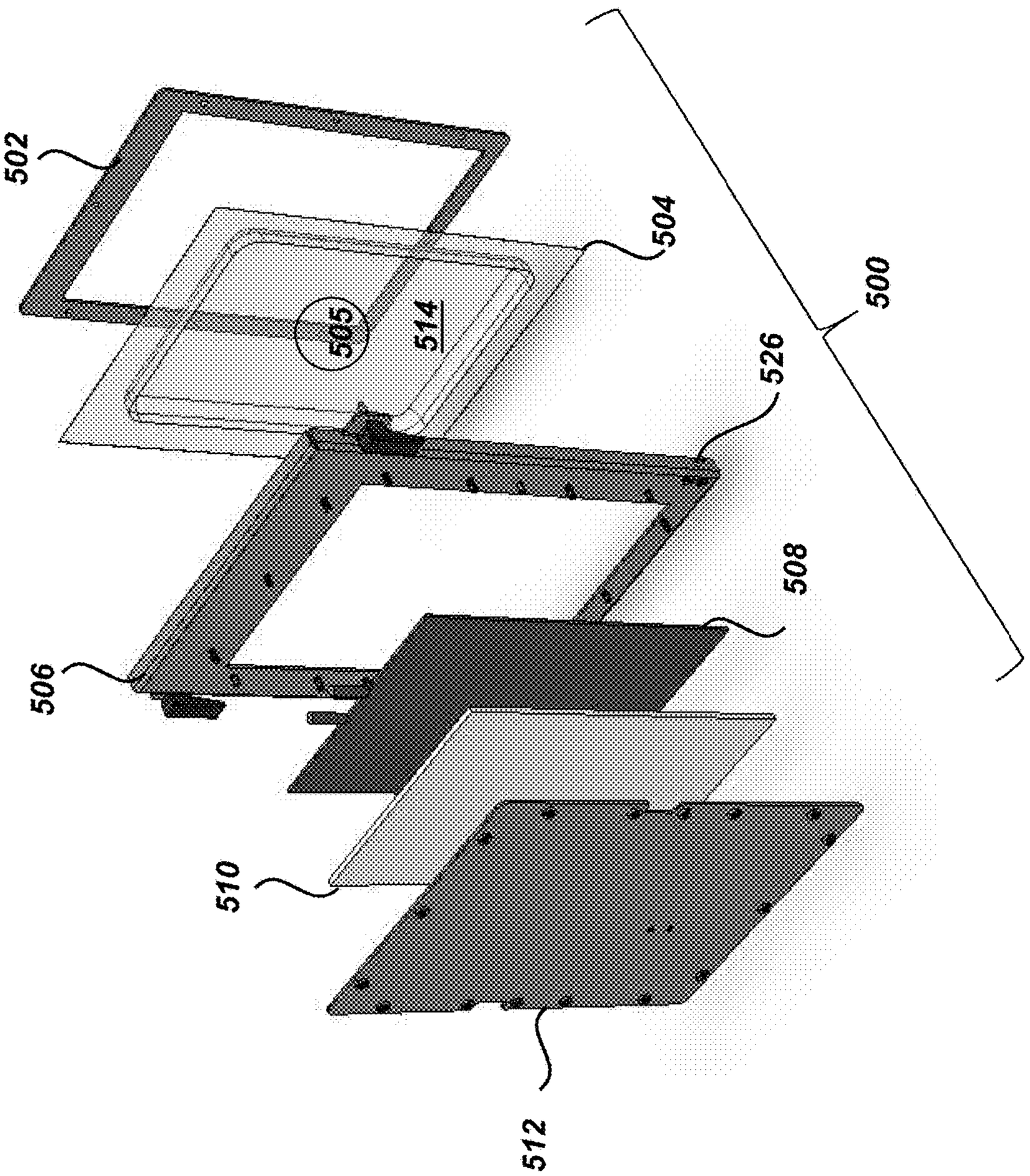


FIG. 4

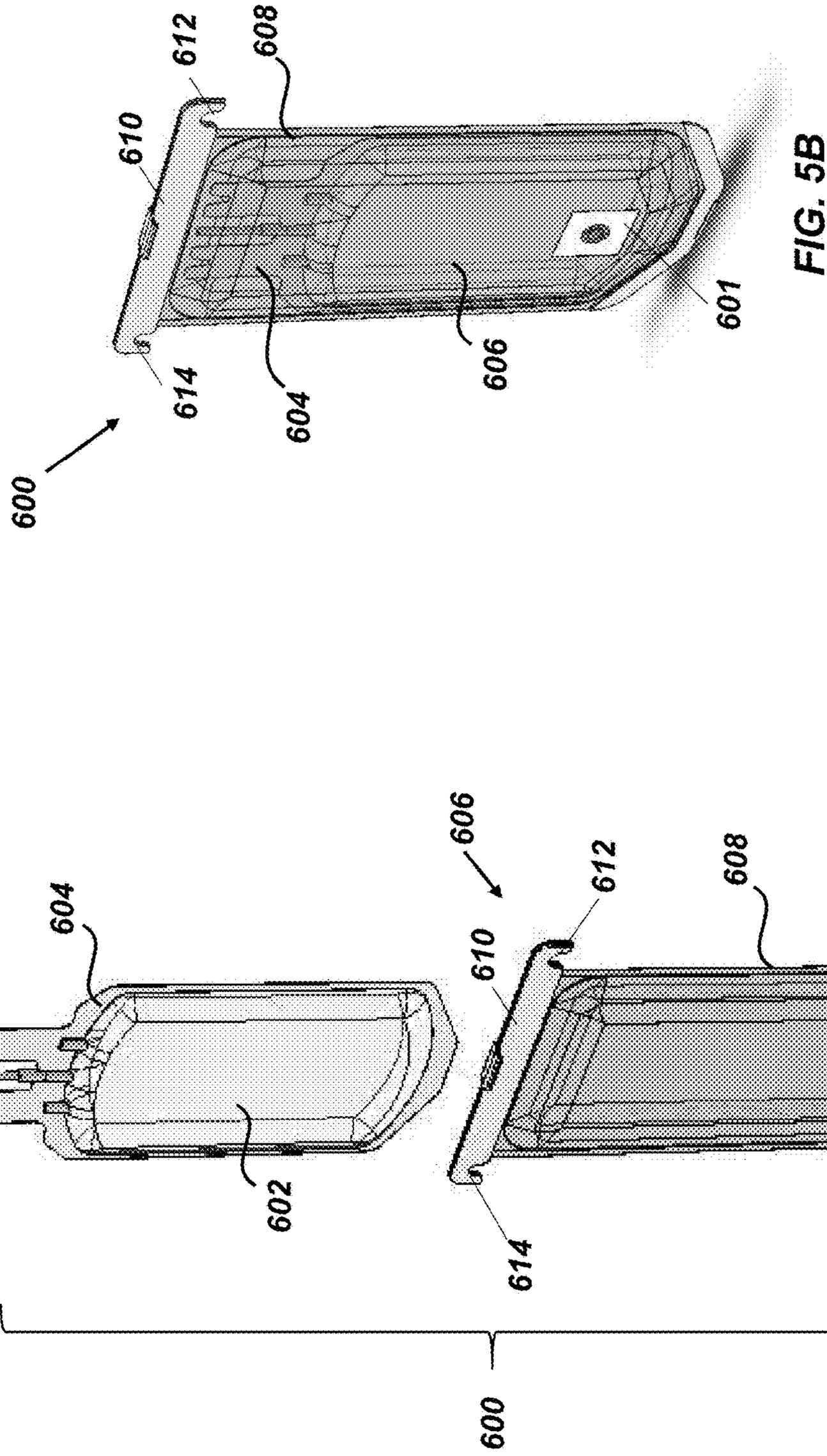


FIG. 5A

FIG. 5B

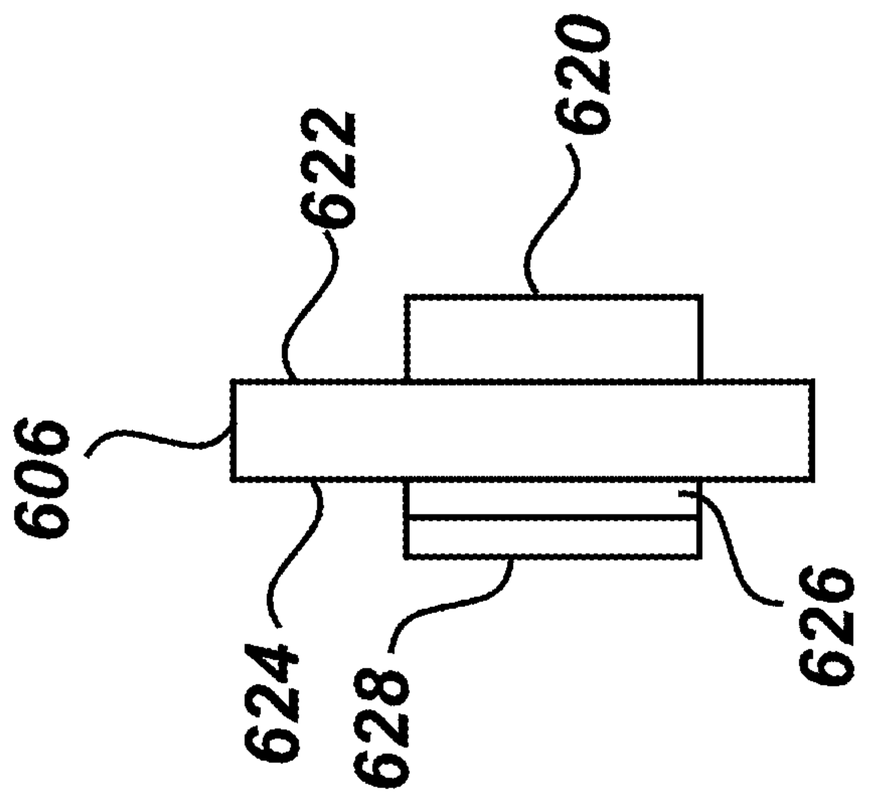


FIG. 5C

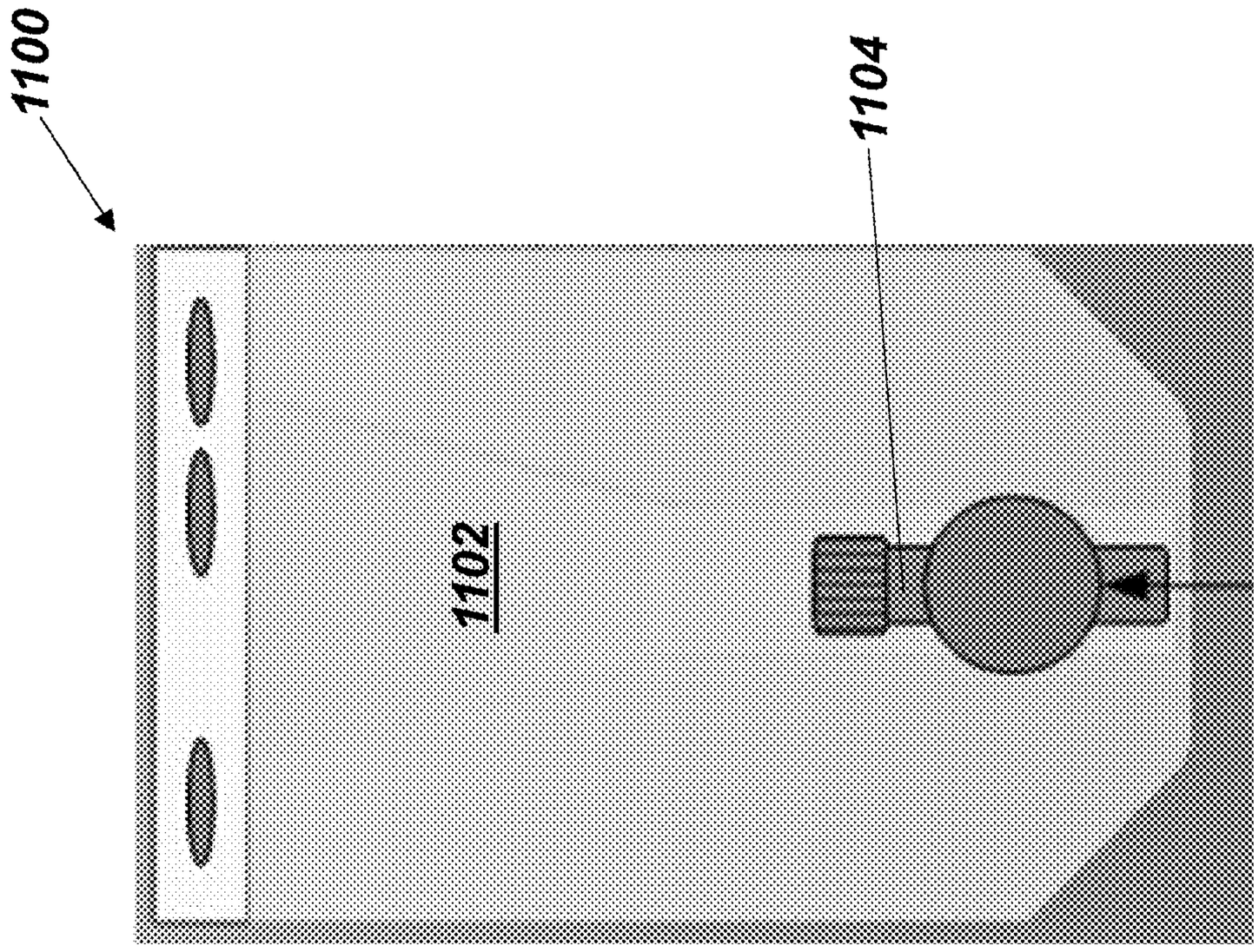


FIG. 7

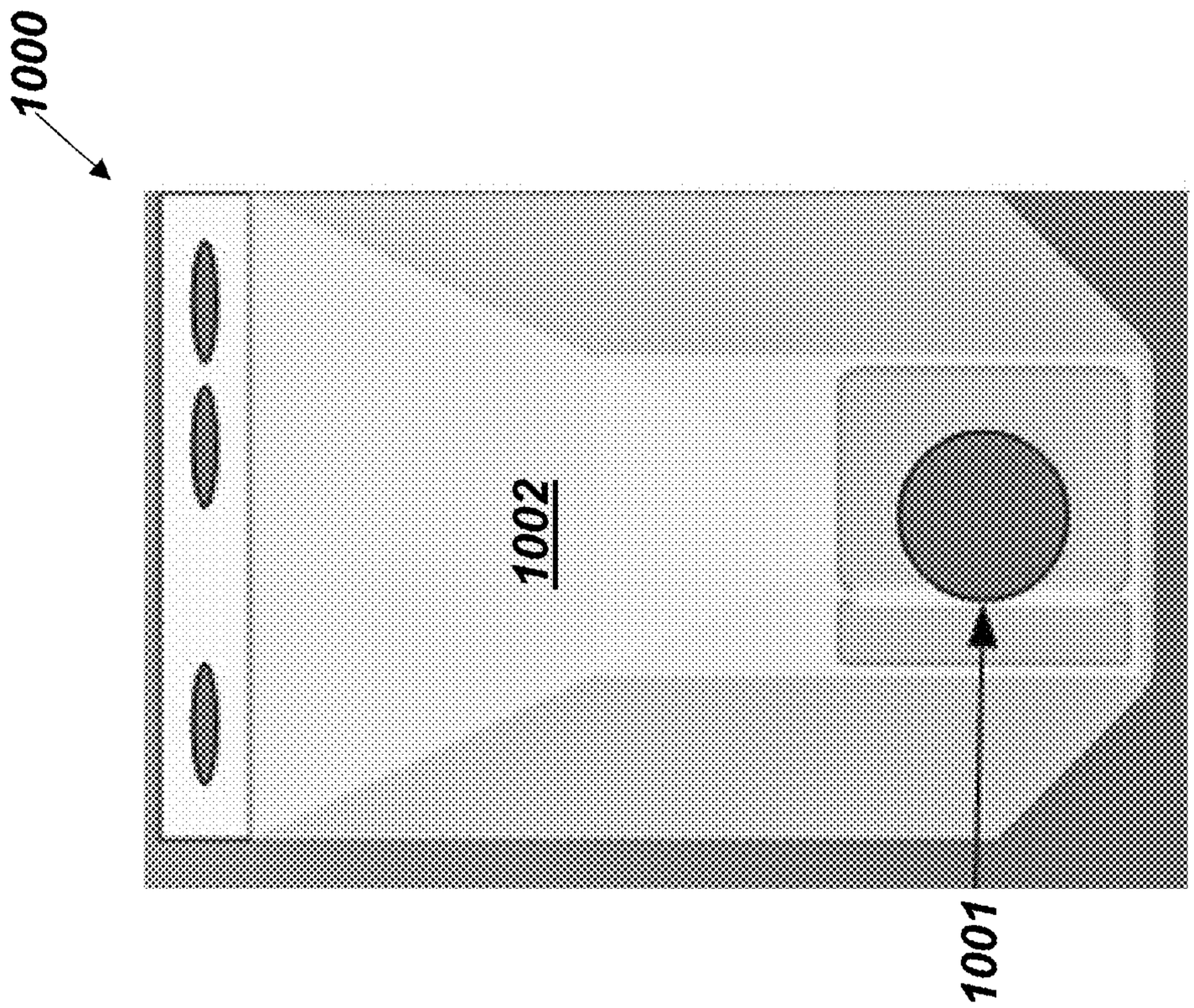


FIG. 6

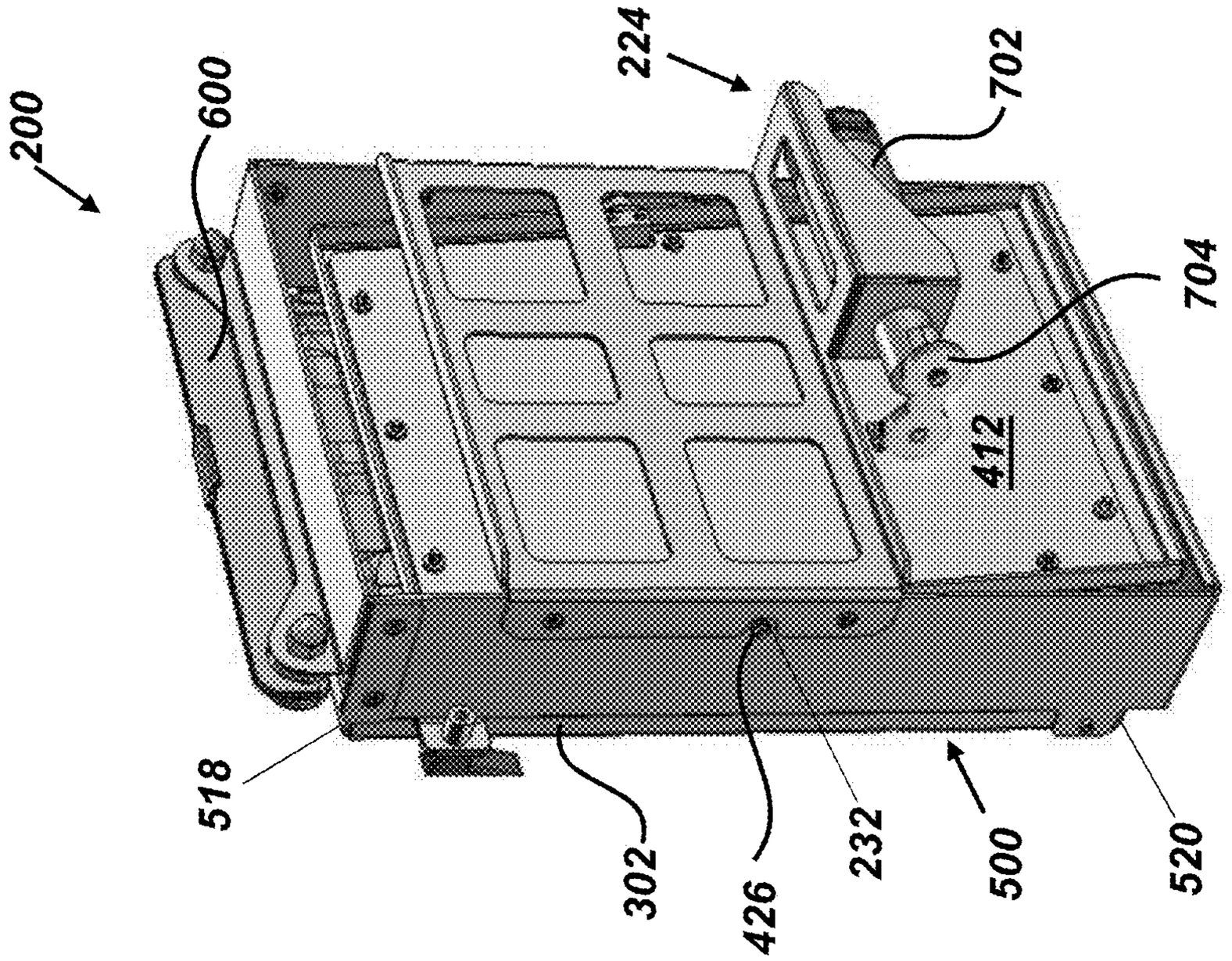

200
600
224
702
704
412
518
302
426
232
500
520

FIG. 8B

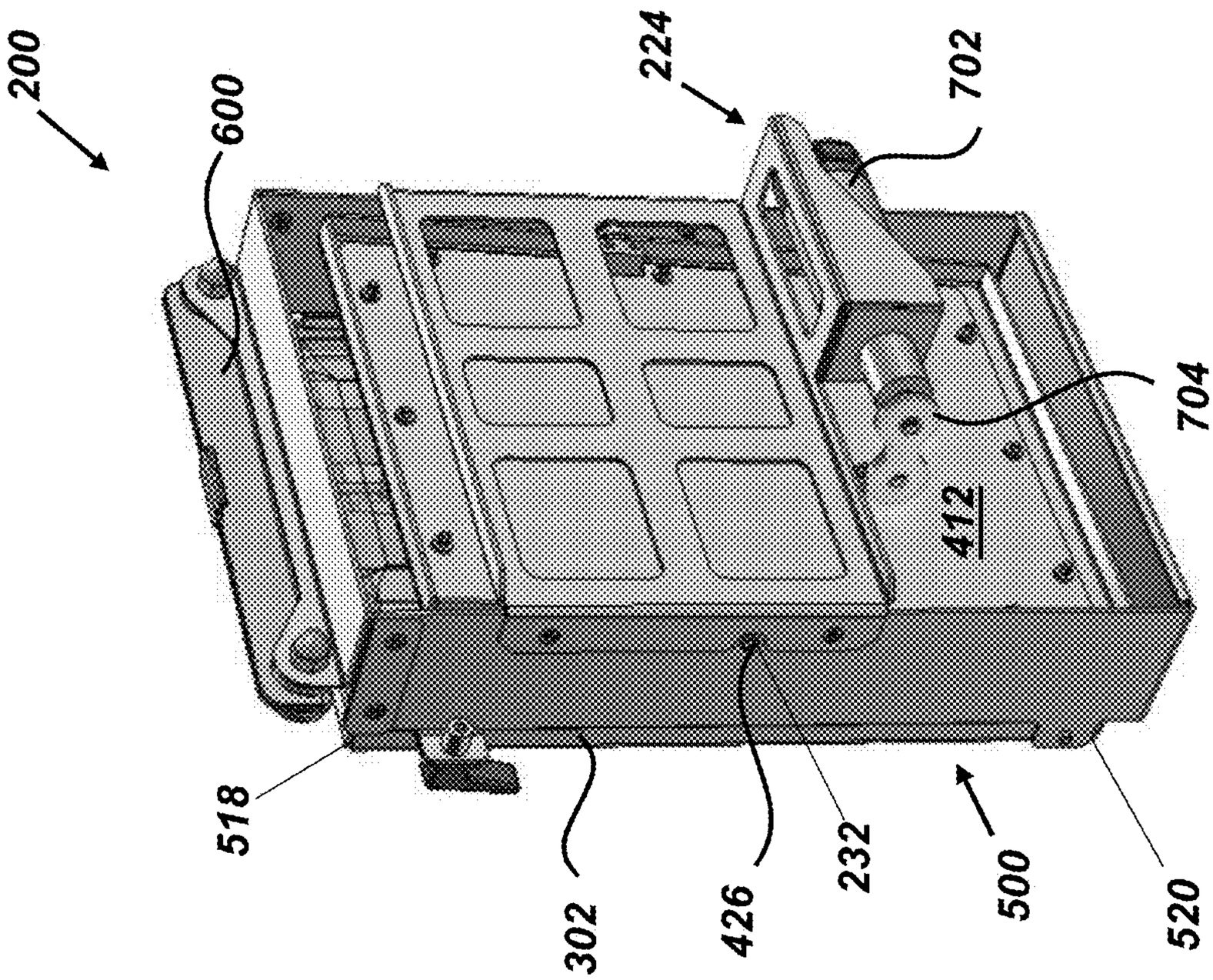

200
600
224
702
704
412
518
302
426
232
500
520

FIG. 8A

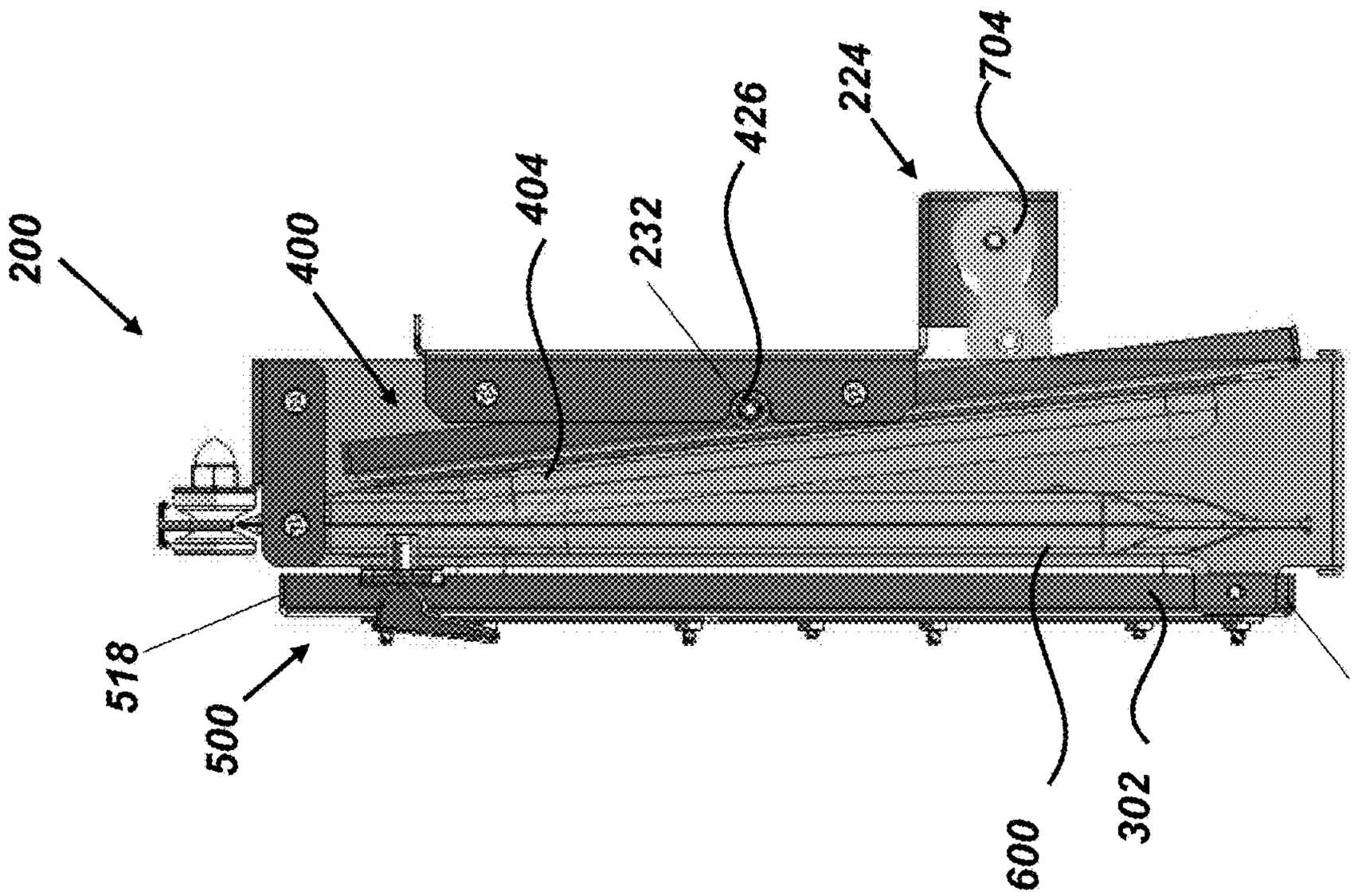

200
400
404
232
426
224
704
518
500
600
302
520

FIG. 8D

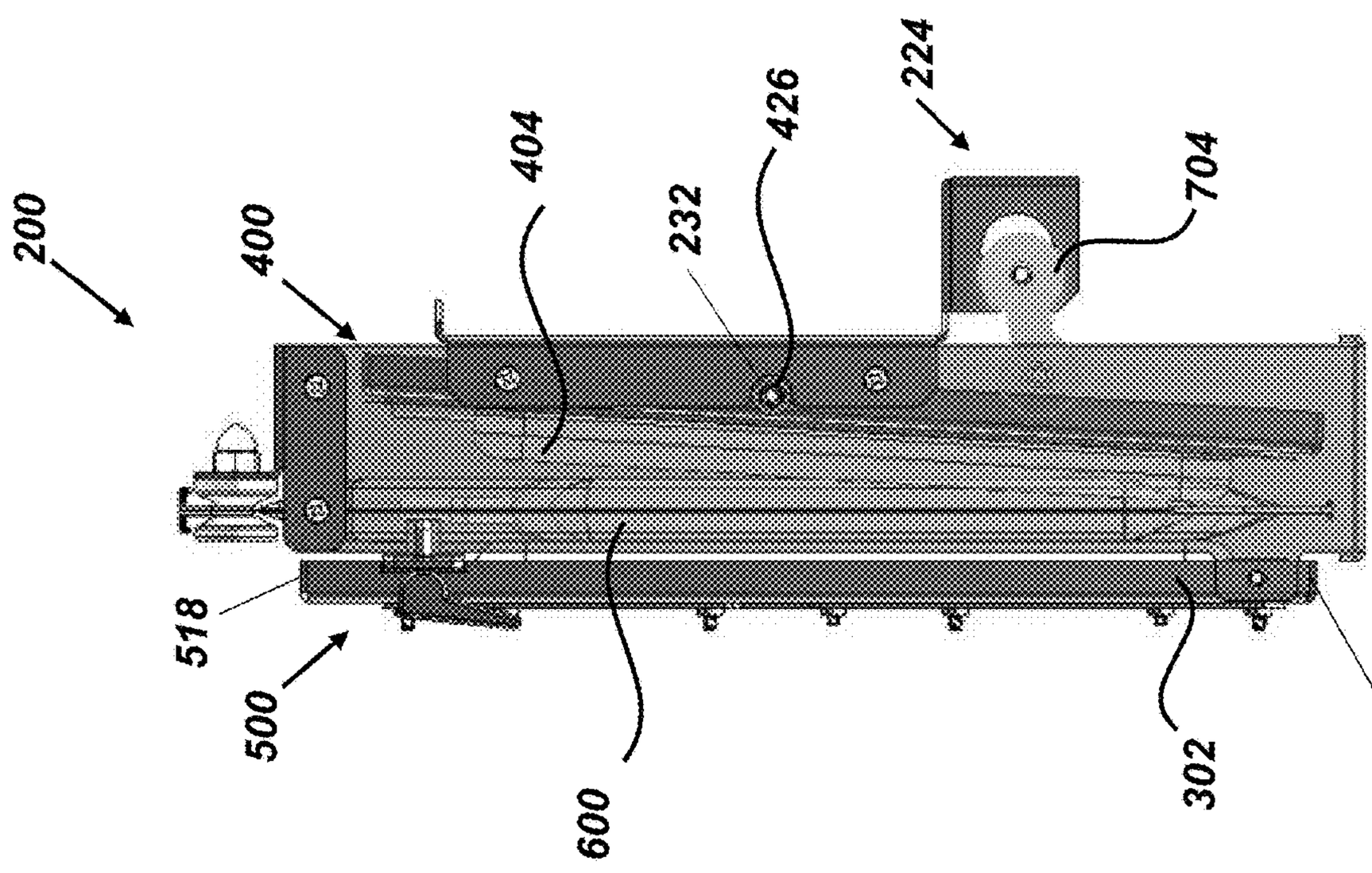

200
400
404
232
426
224
704
518
500
600
302
520

FIG. 8C

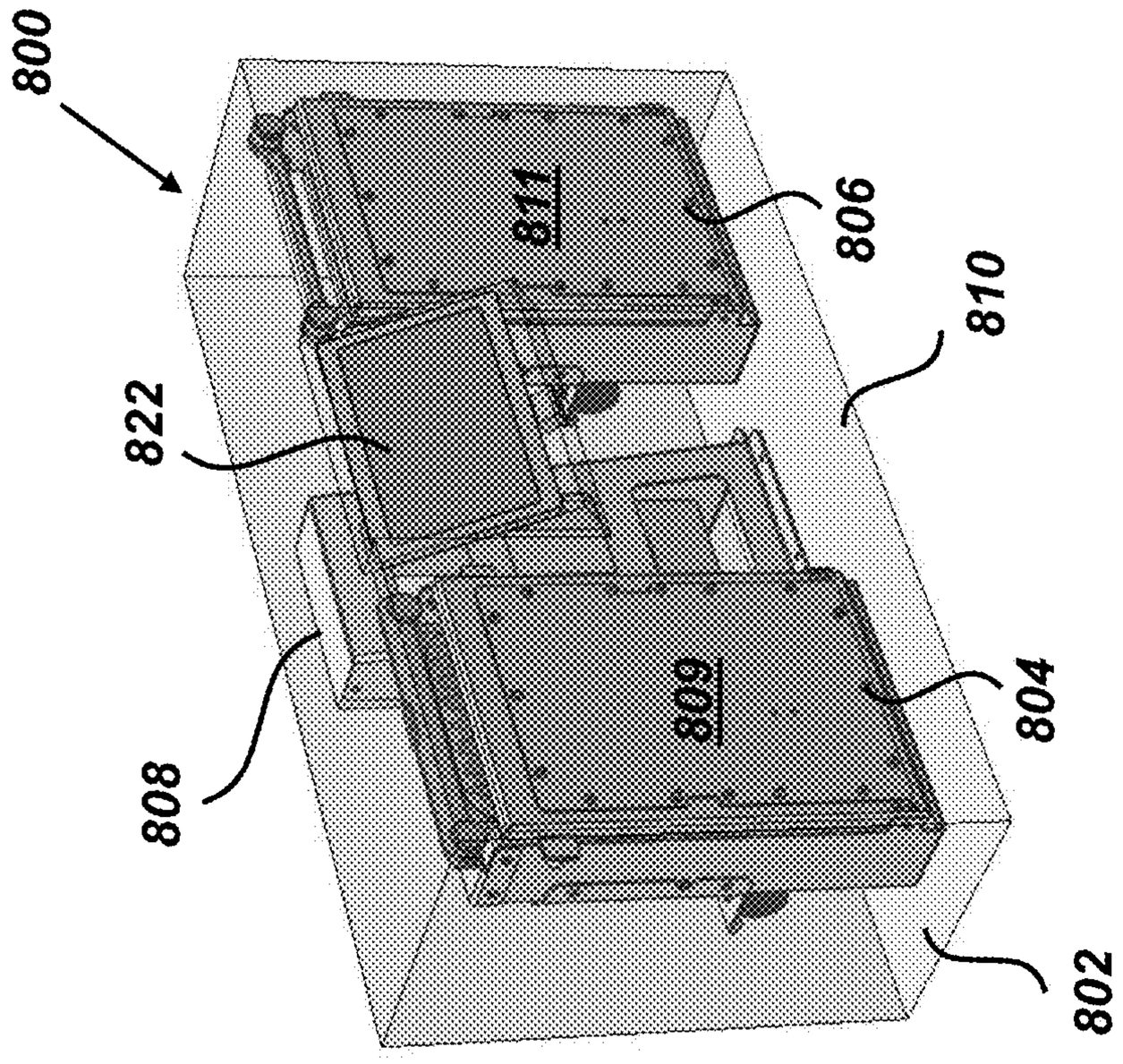

800
811
806
810
822
808
809
804
802

FIG. 9B

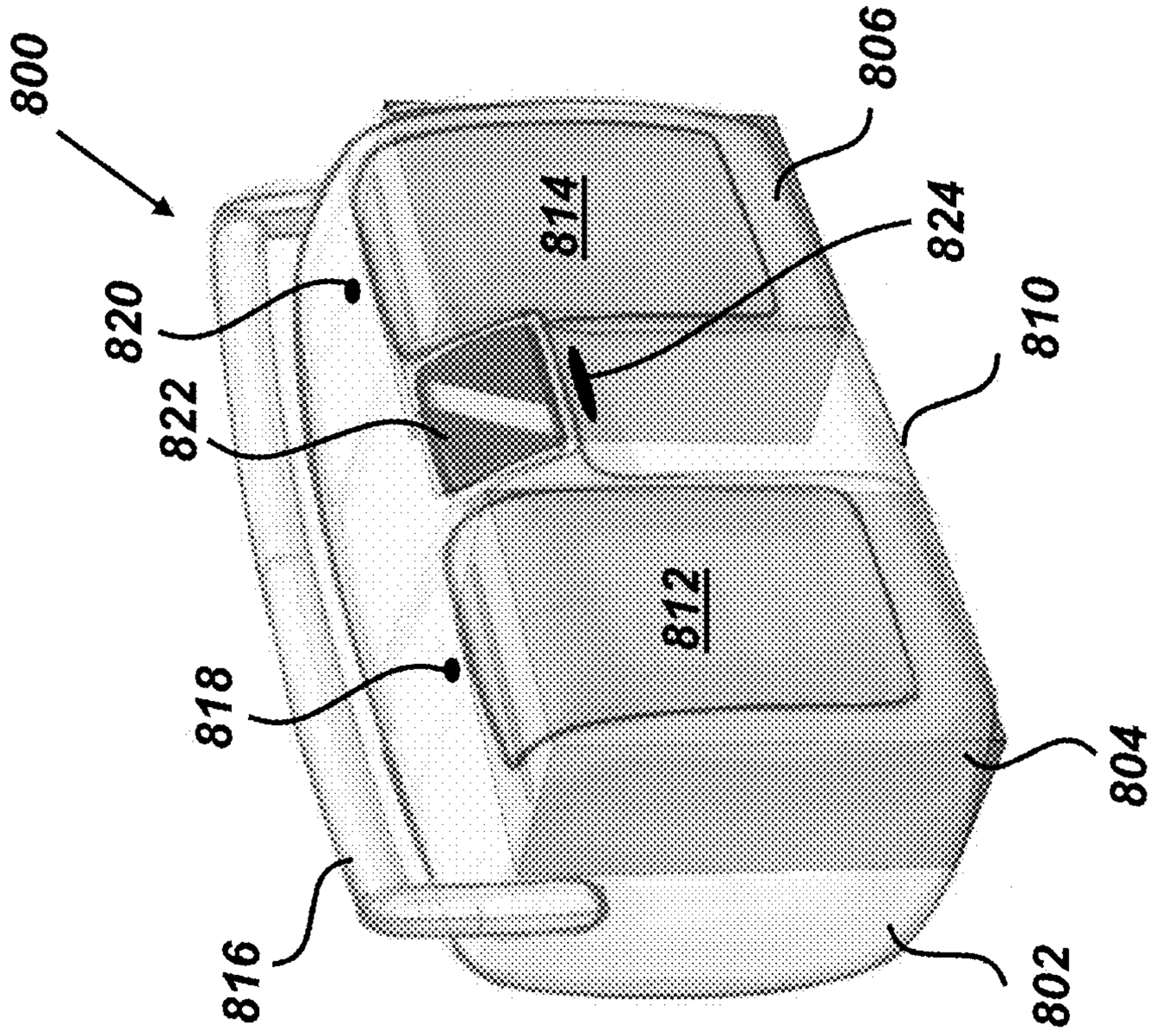

800
806
814
824
820
810
822
812
818
804
816
802

FIG. 9A

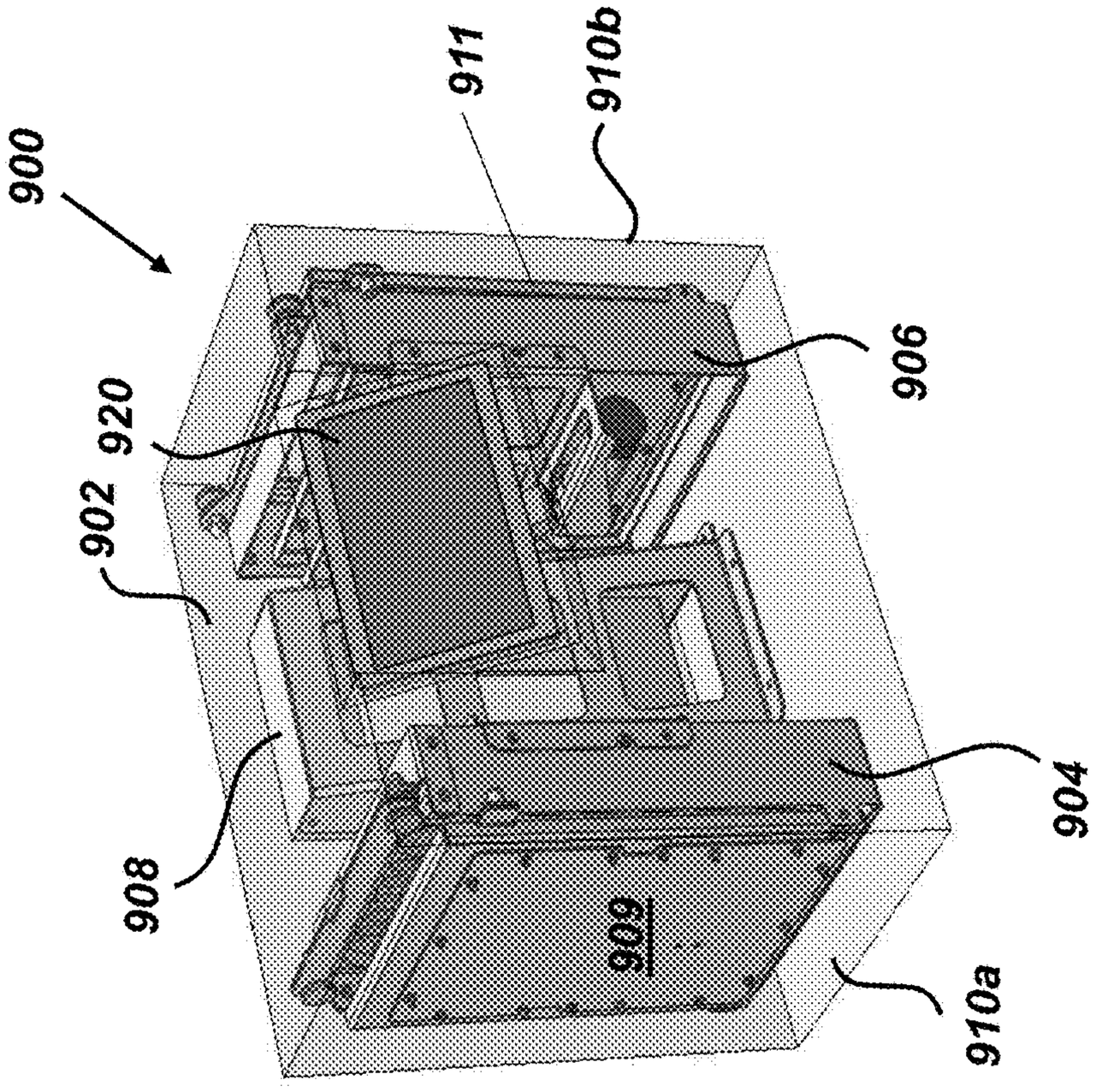


FIG. 10B

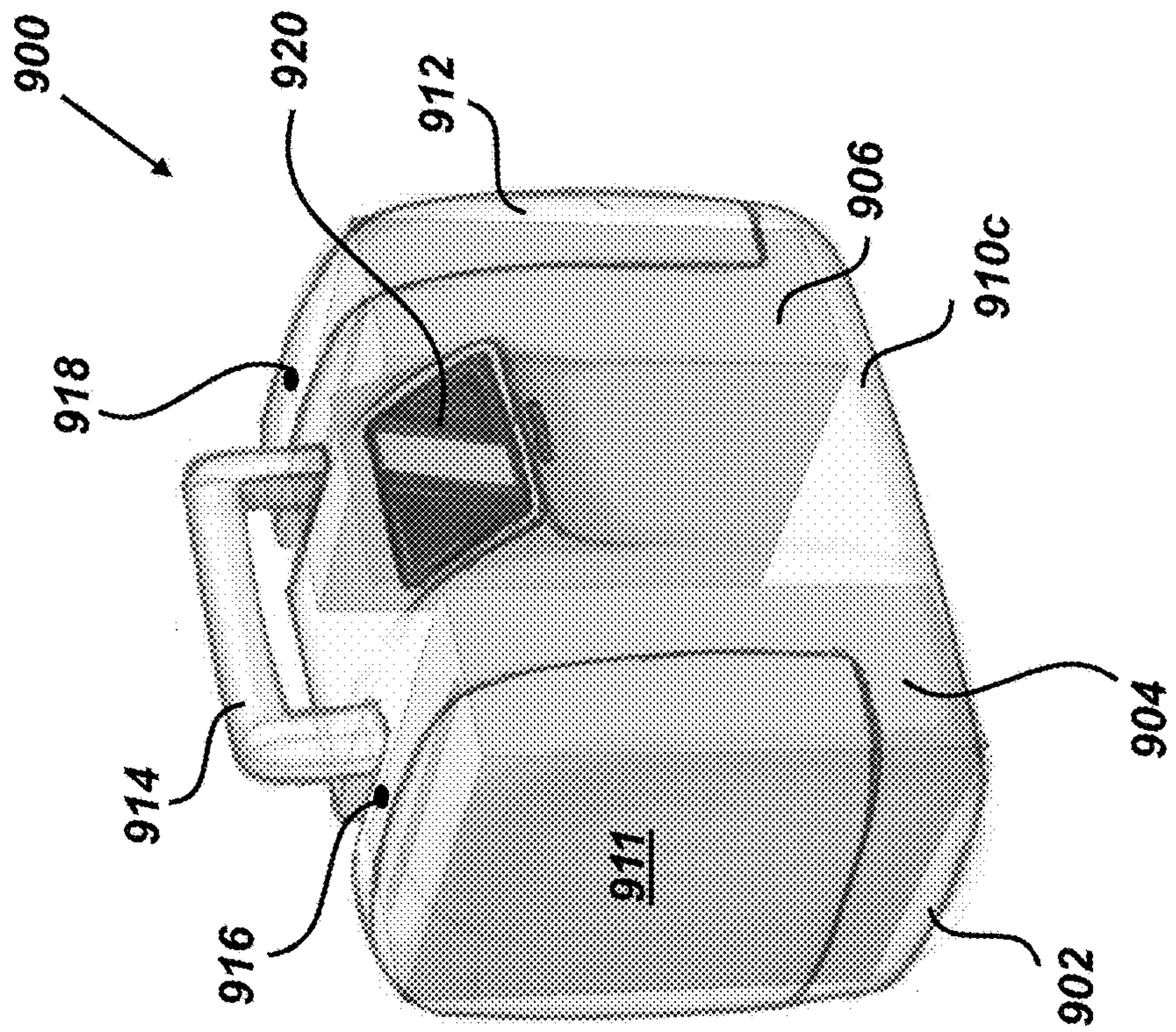


FIG. 10A

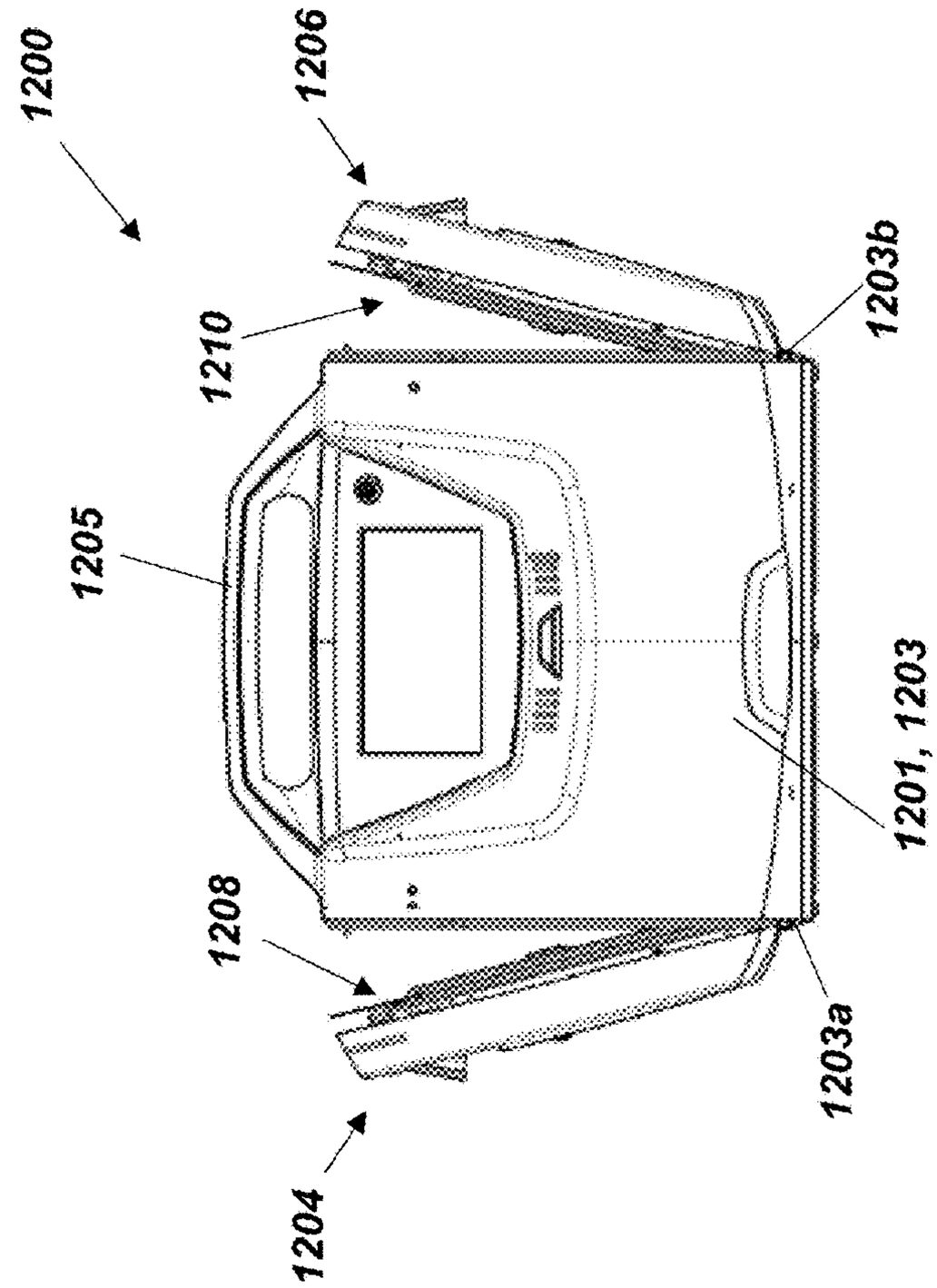


FIG. 11B

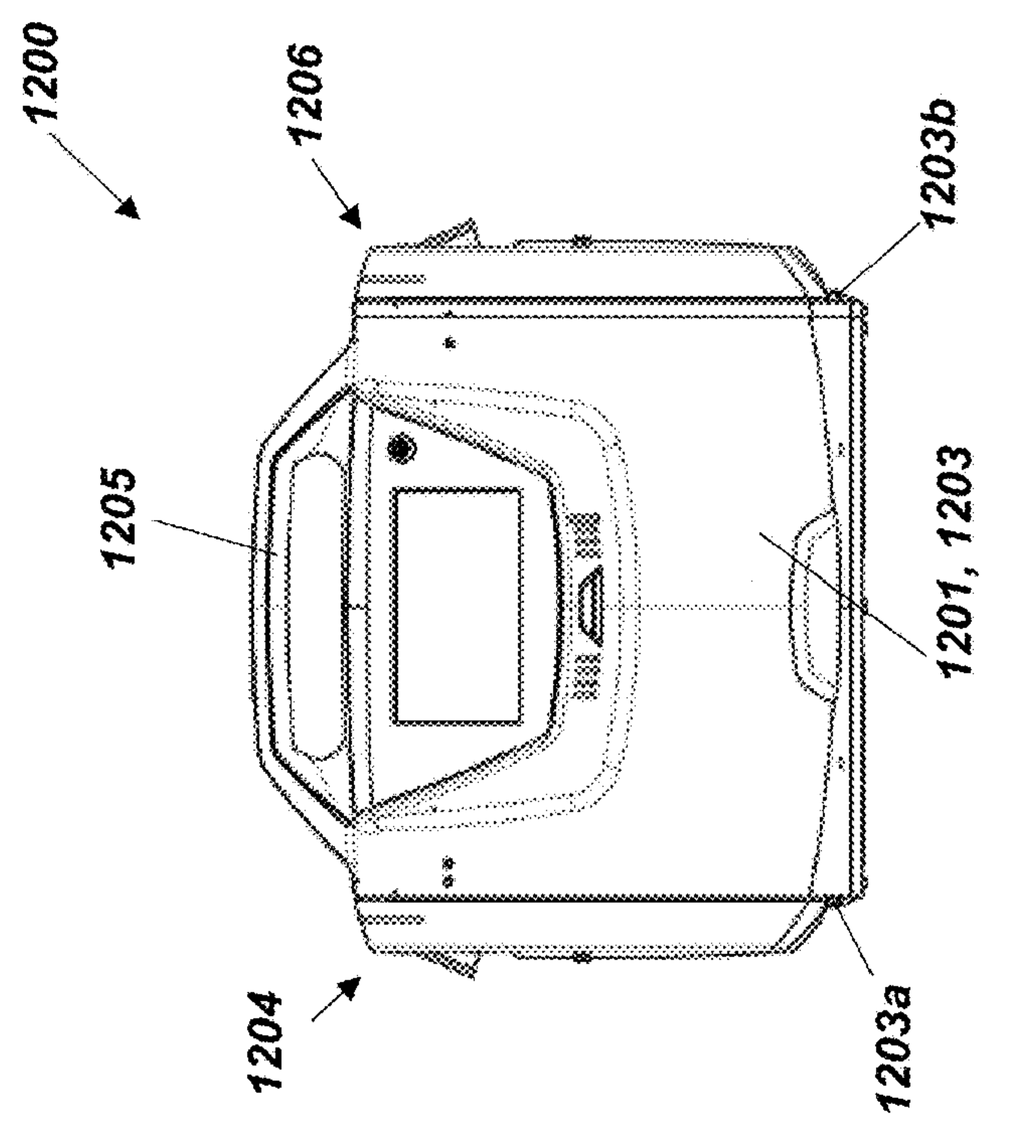


FIG. 11A

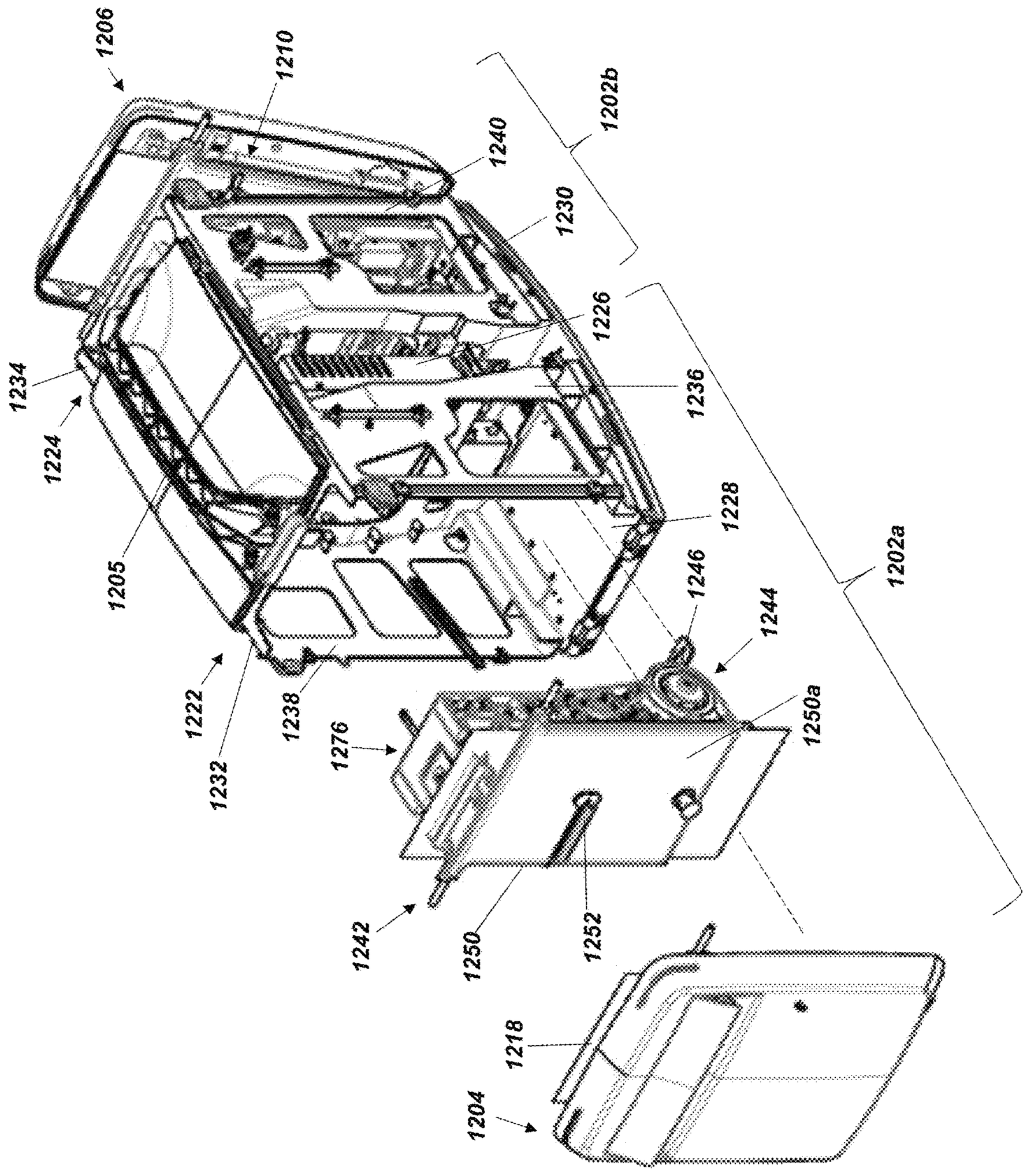

1206
1210
1240
1202b
1230
1226
1234
1224
1236
1205
1228
1246
1244
1222
1238
1276
1250a
1232
1202a
1242
1250
1252
1218
1204

FIG. 11C

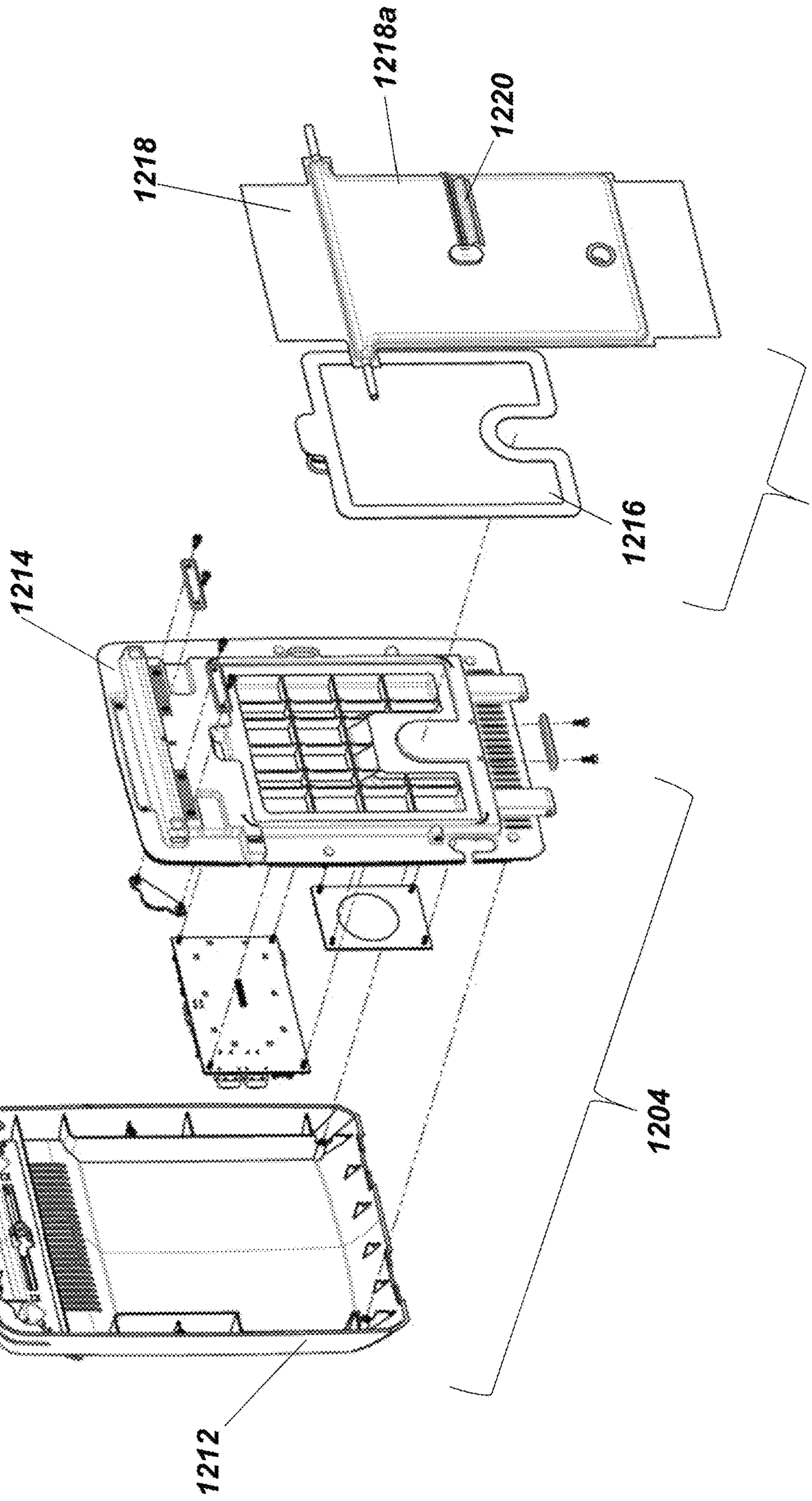


FIG. 12

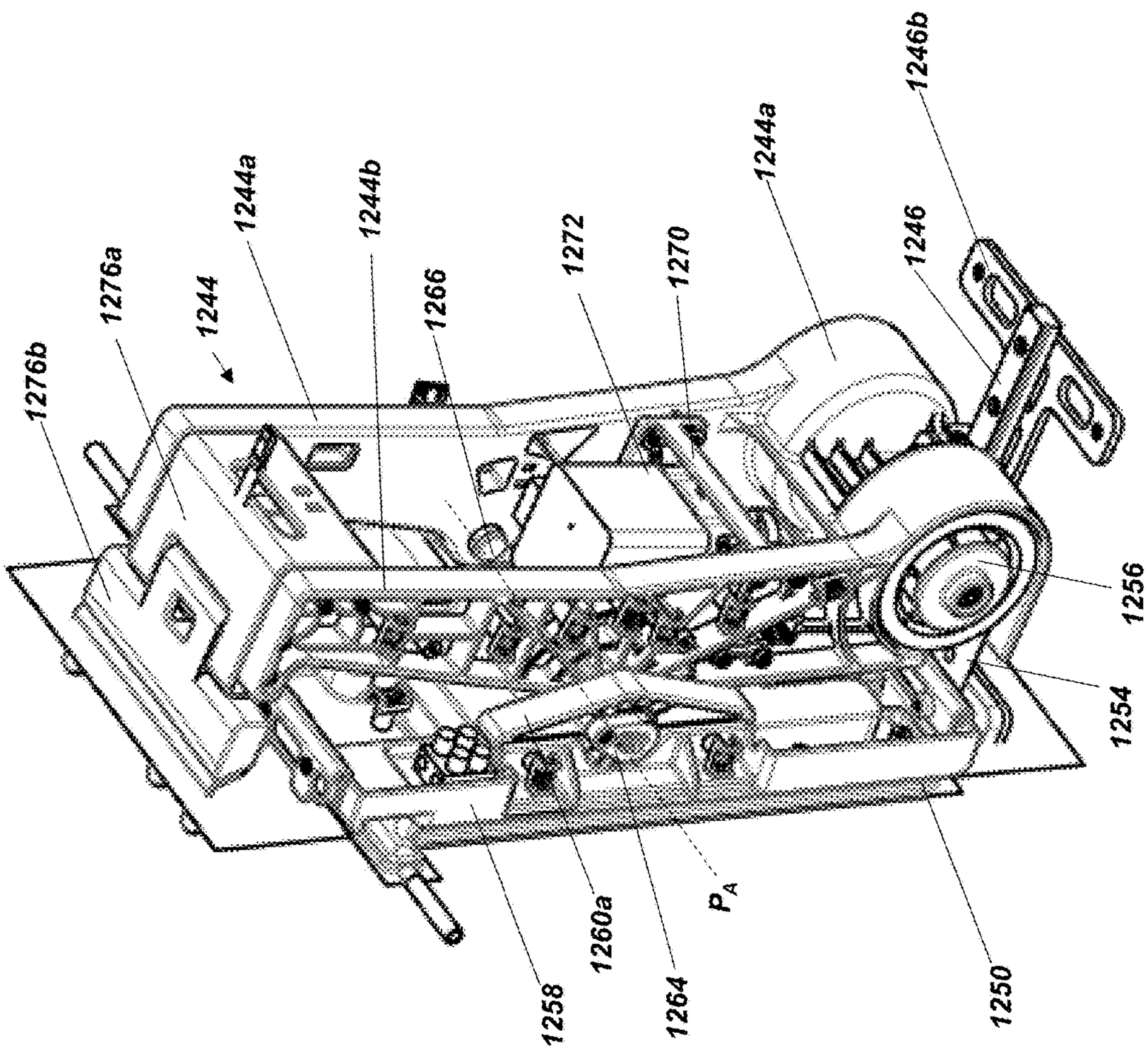

1276b
1276a
1244
1244a
1244b
1266
1272
1270
1244a
1246
1246b
1256
1254
1260a
P_A
1258
1264
1250

FIG. 13A

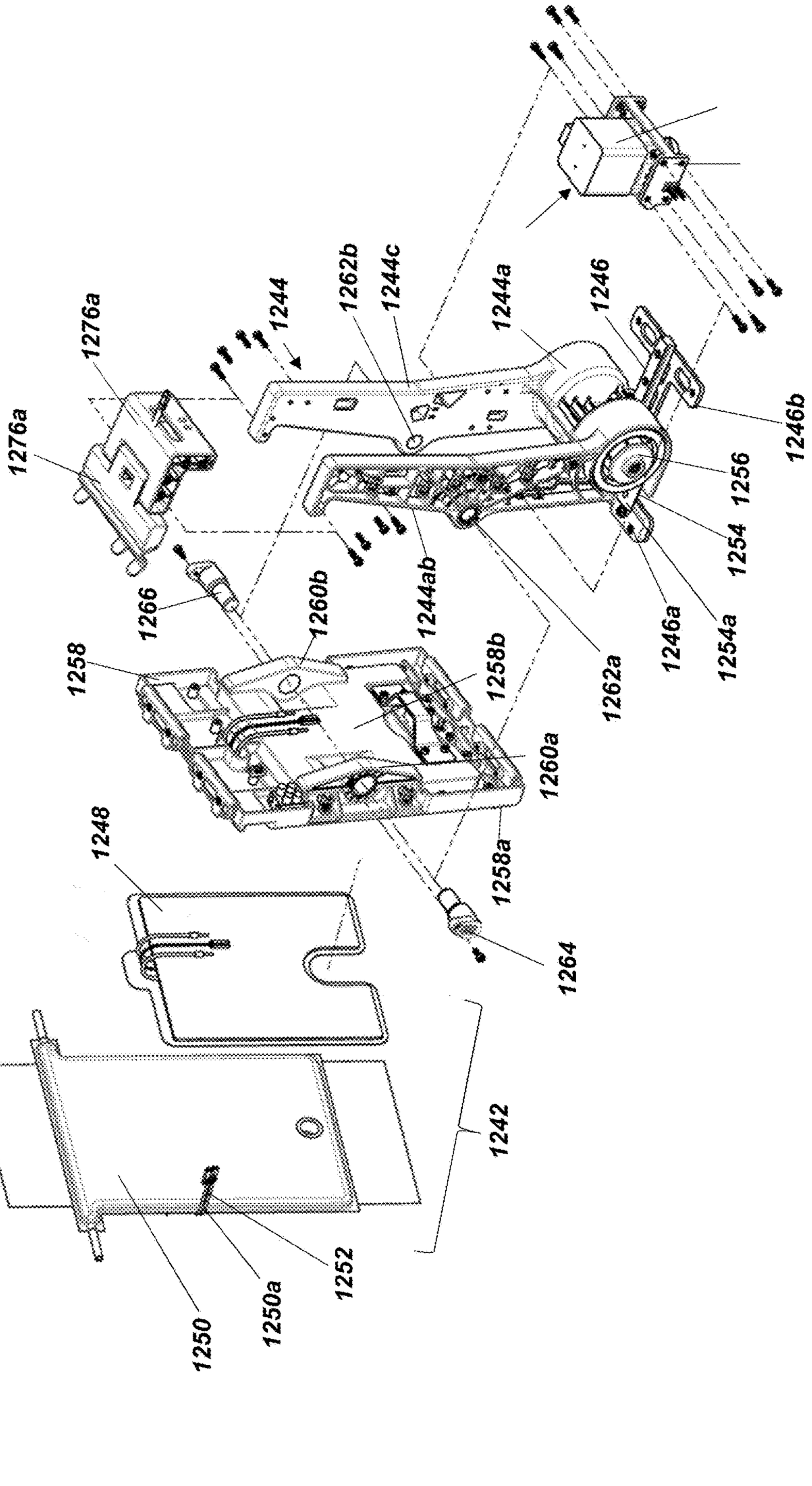

1276a
1276a
1244
1262b
1244c
1244a
1246
1246b
1256
1254
1254a
1246a
1262a
1244ab
1266
1260b
1258
1258b
1260a
1258a
1264
1248
1242
1250
1250a
1252

FIG. 13B

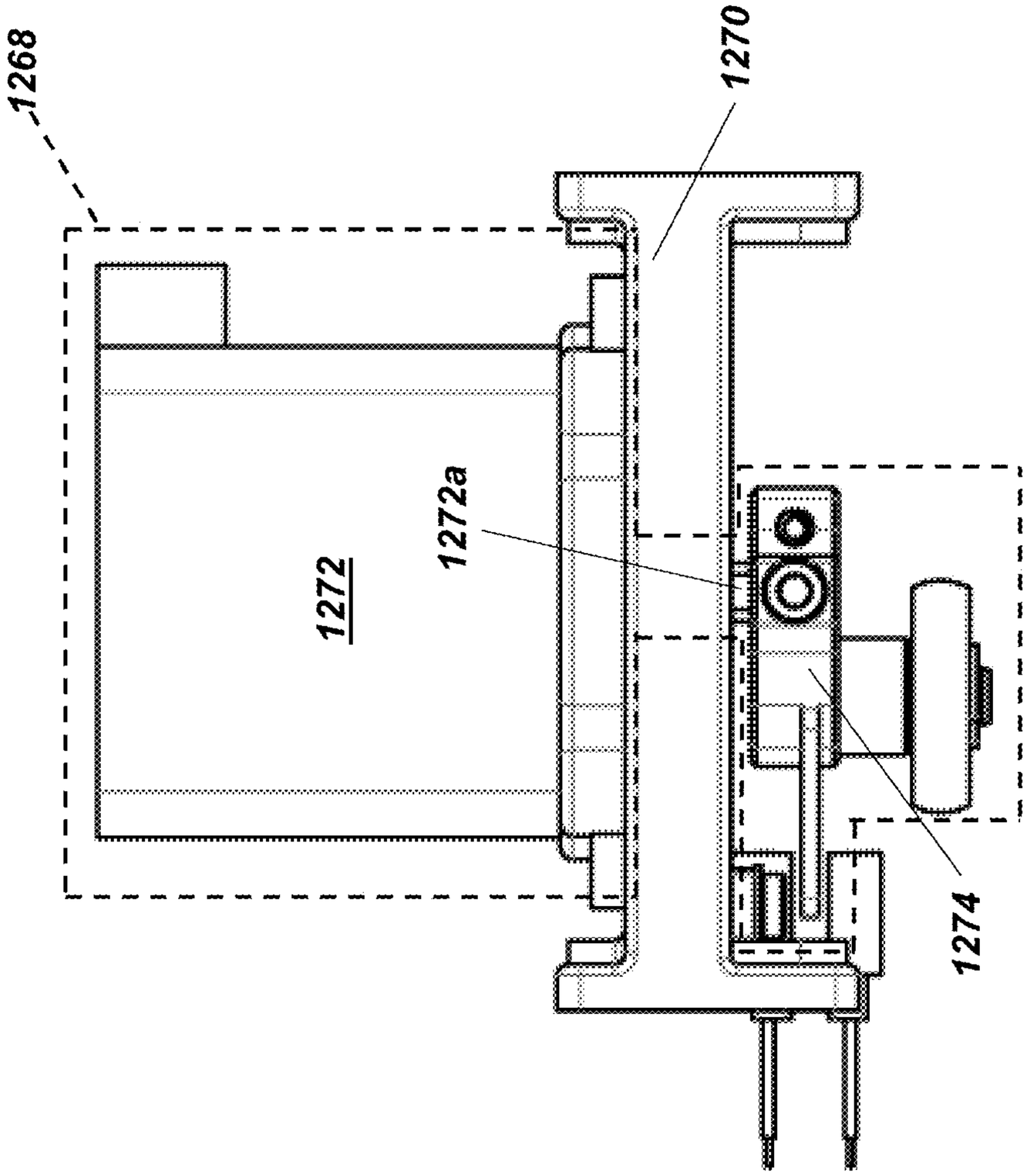


FIG. 14

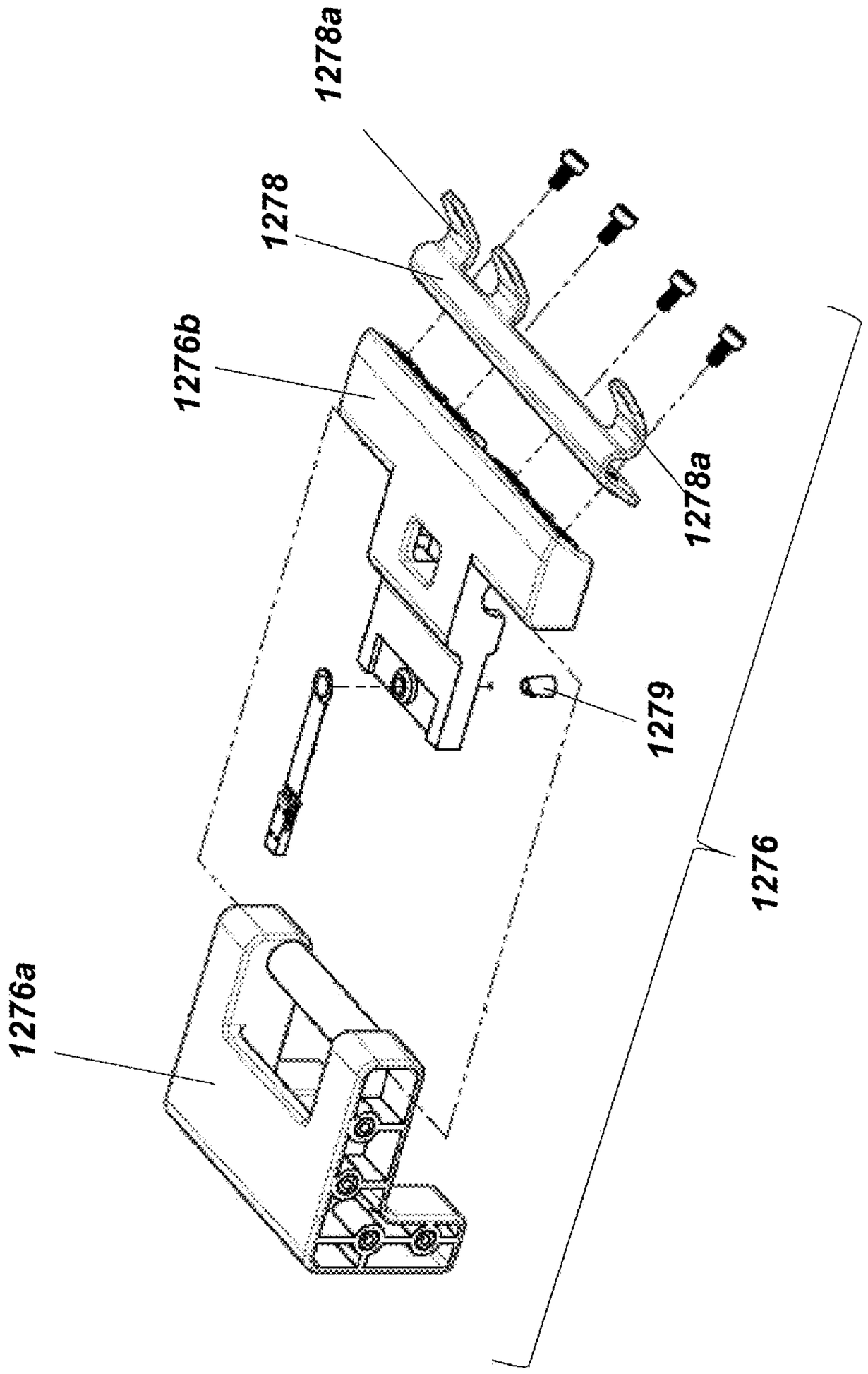


FIG. 15

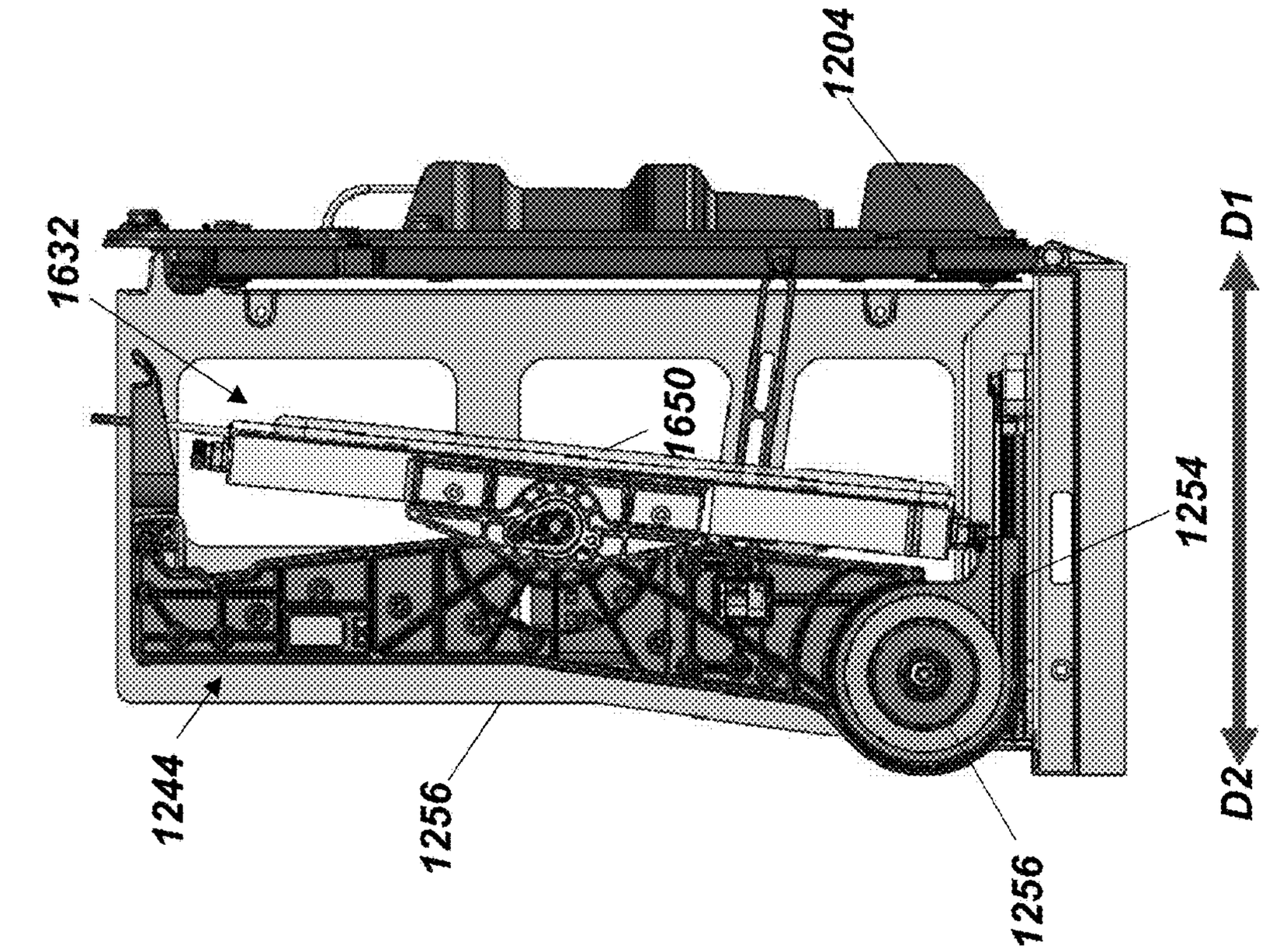


FIG. 16B

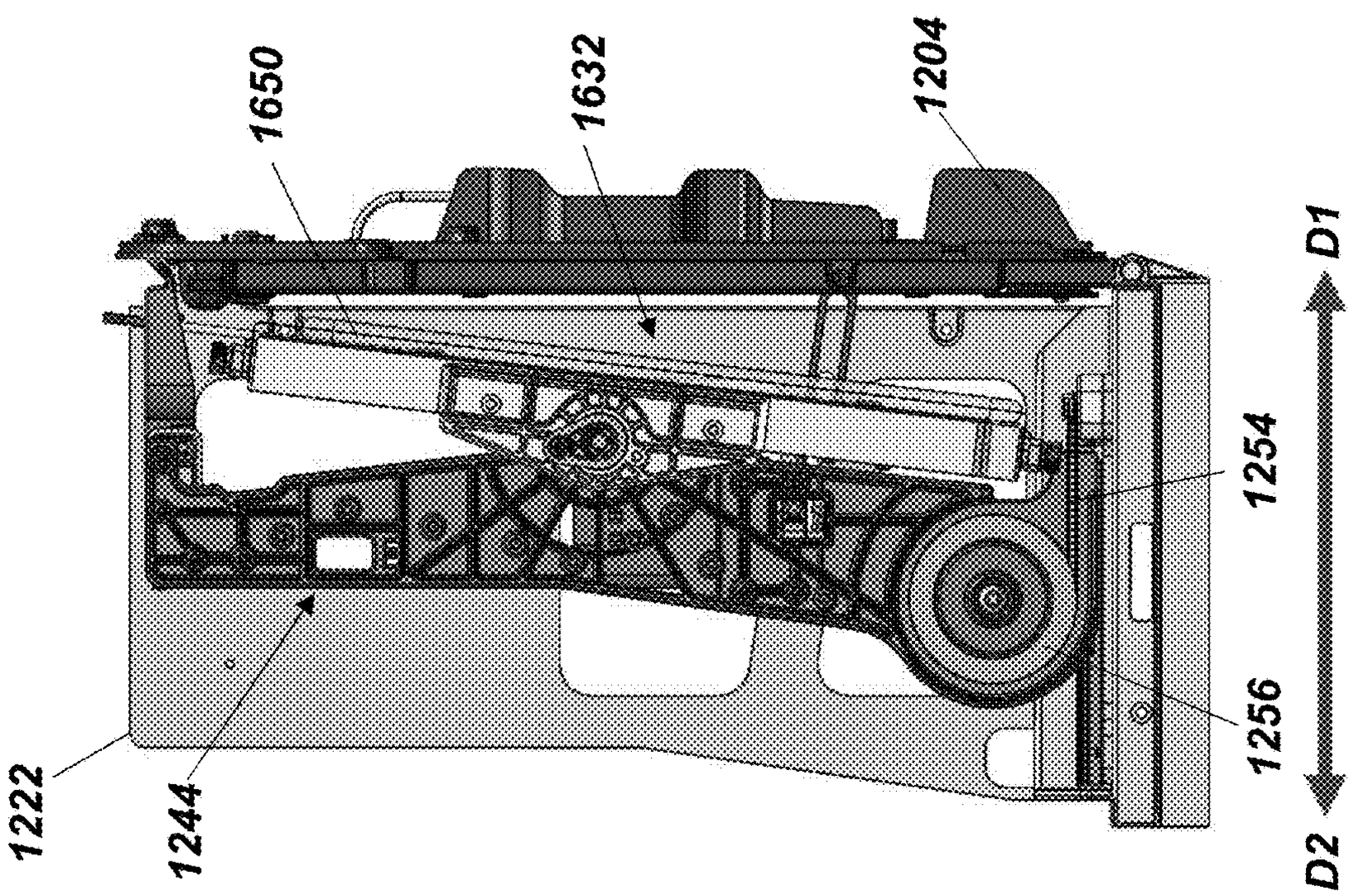


FIG. 16A

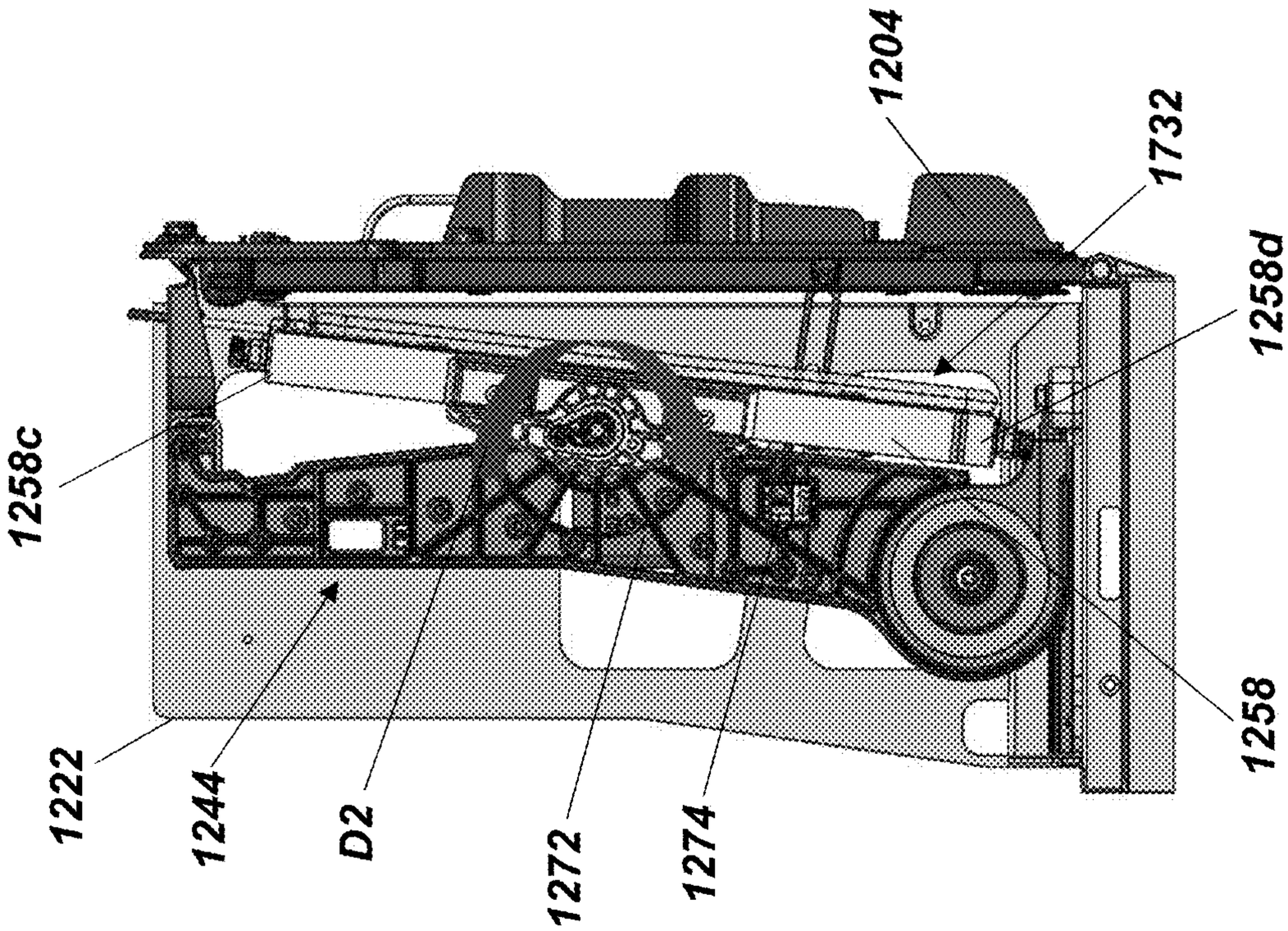


FIG. 17B

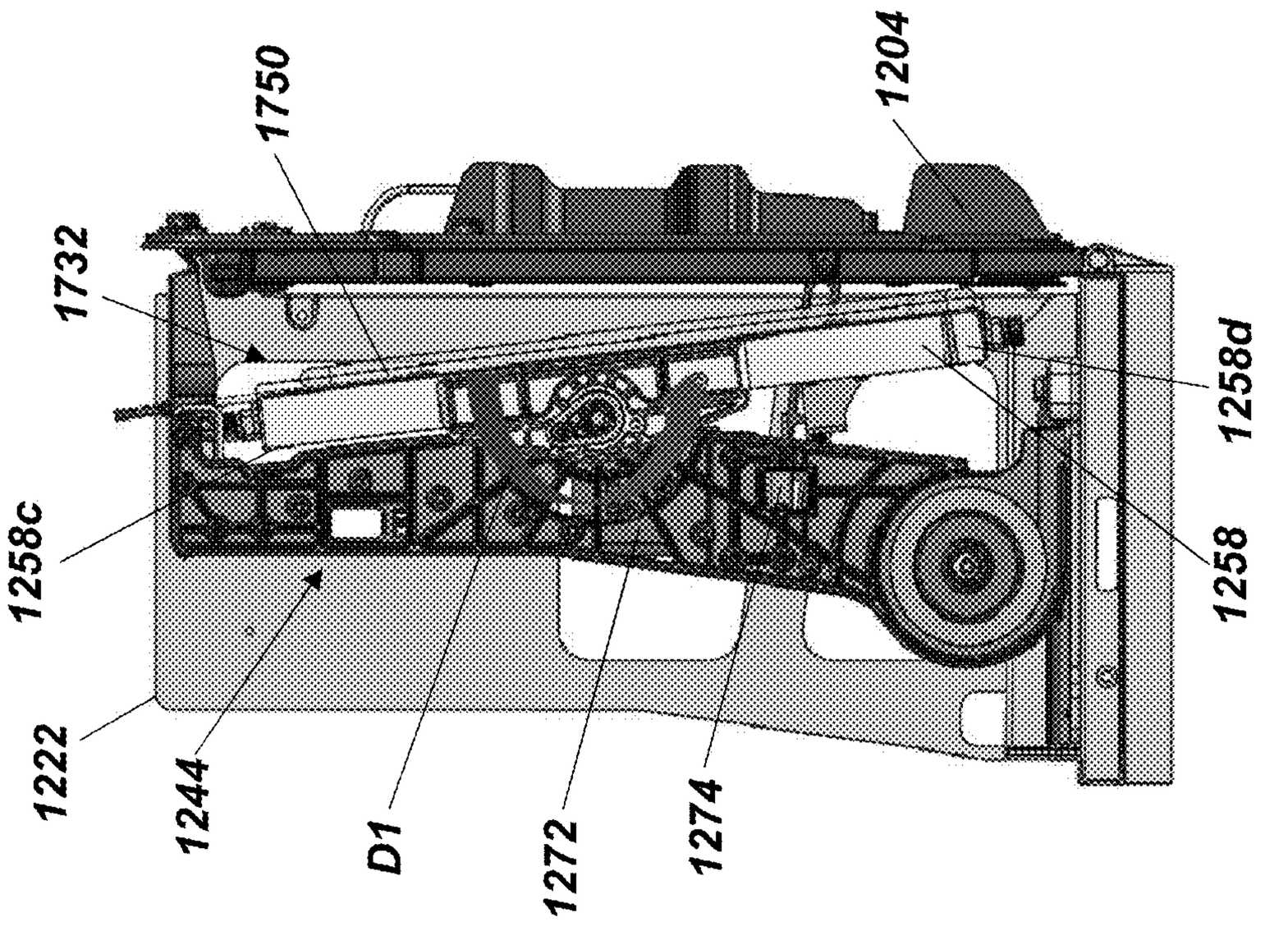


FIG. 17A

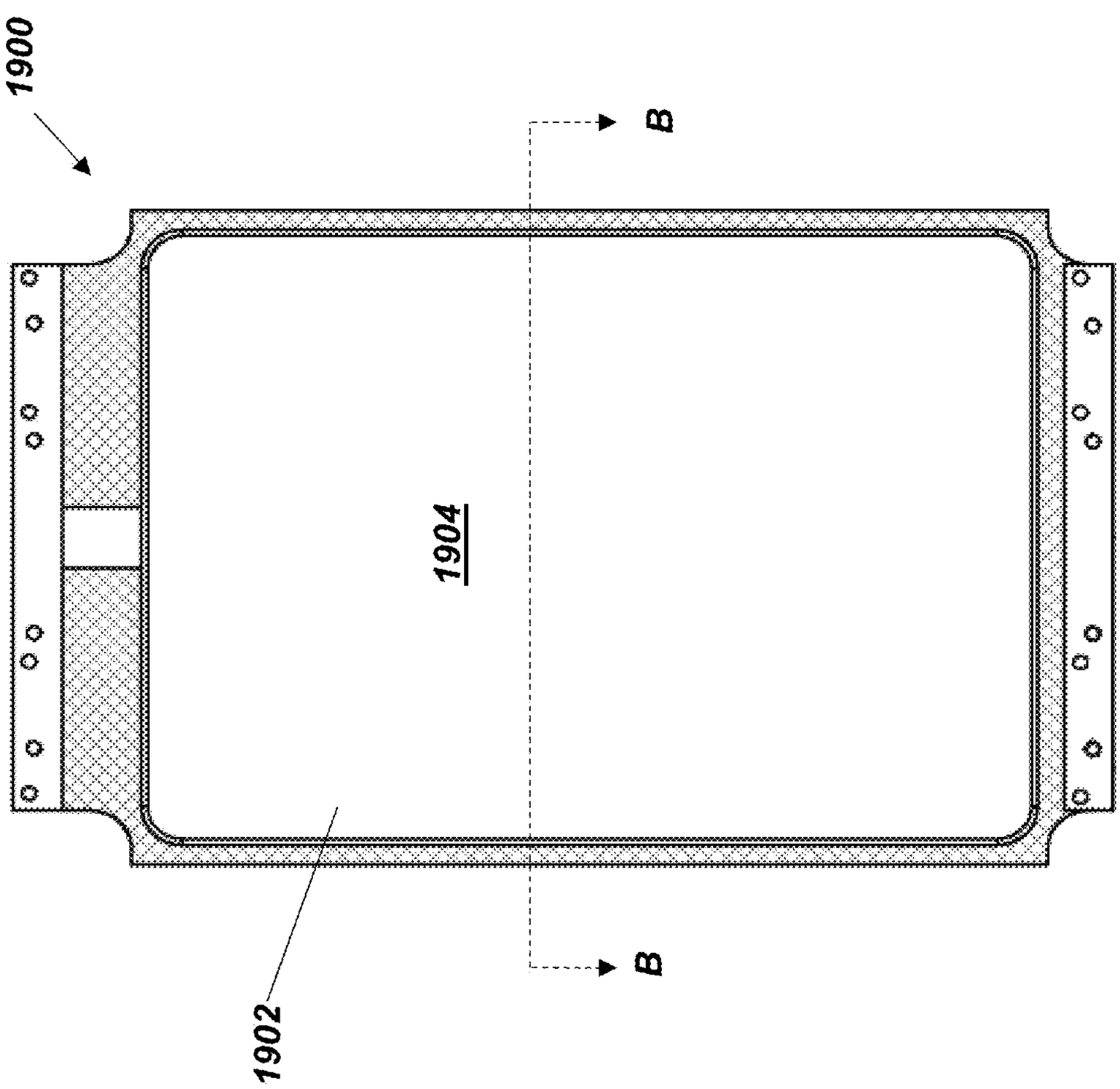


FIG. 18A

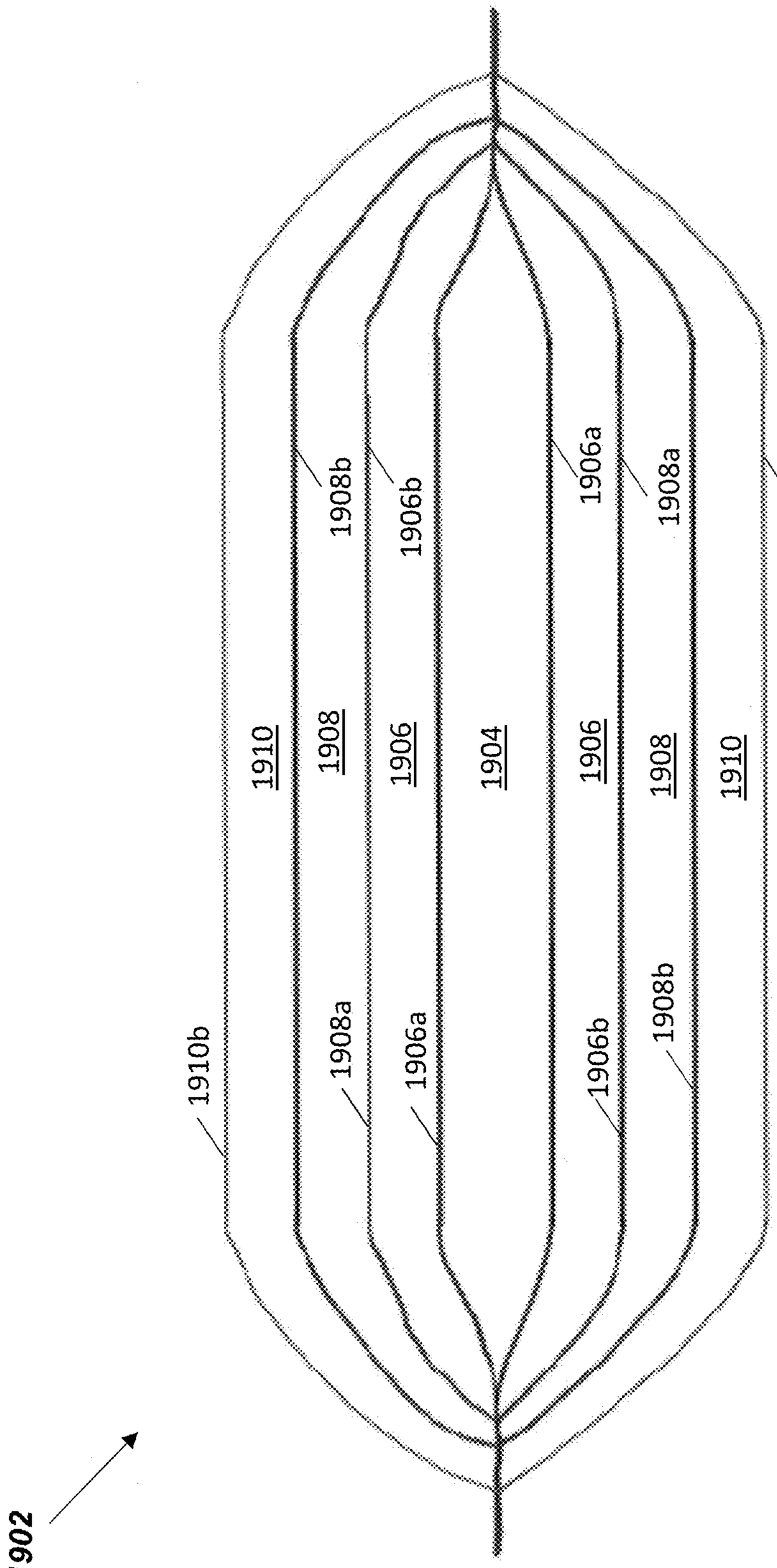

1910b
1908a
1906a
1904
1906b
1908b
1910
1910
1908
1906
1906
1908
1910
1910a
1908b
1906a
1906b
1908a
1902

FIG. 18B

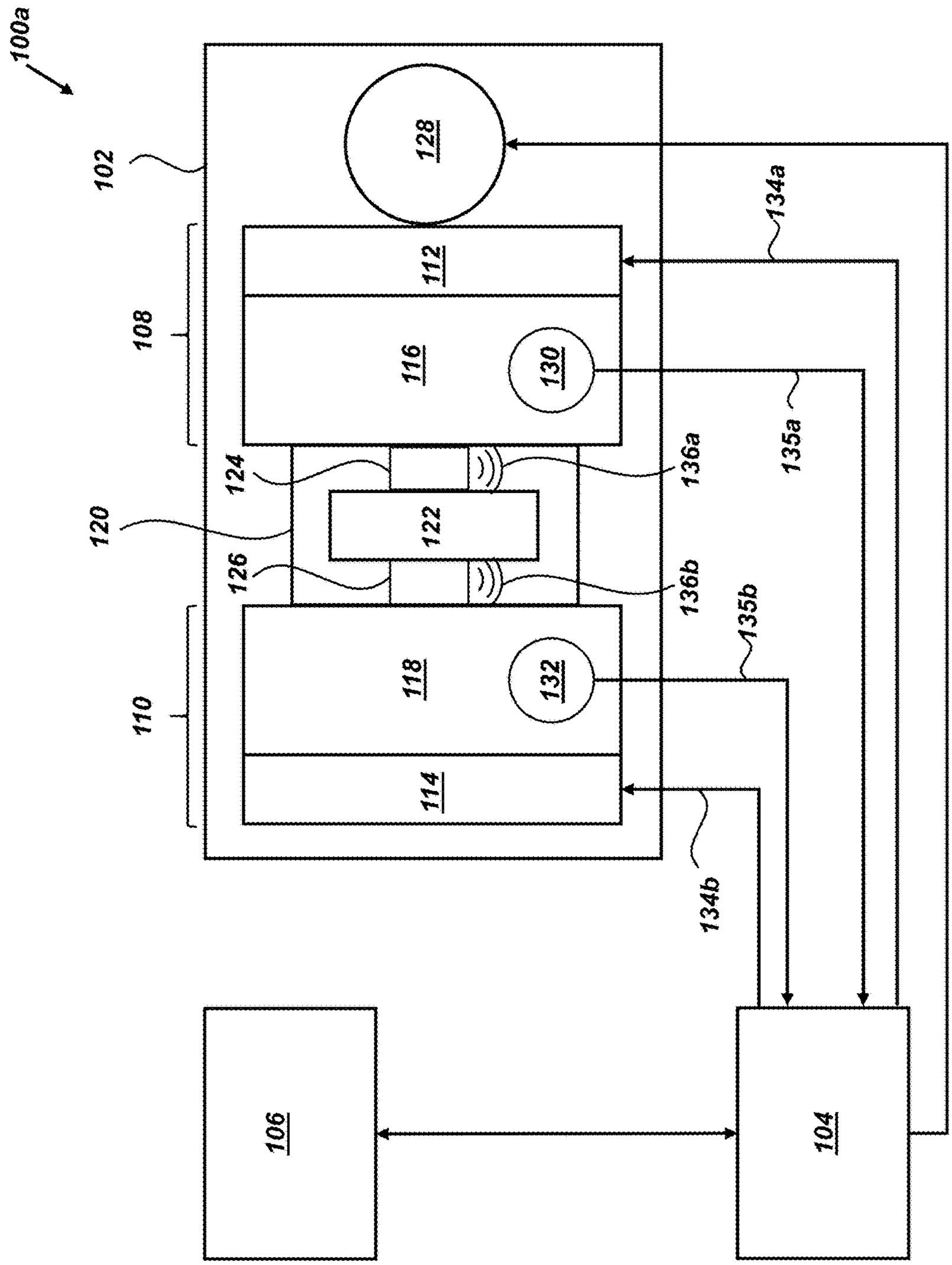

100a
102
128
112
108
116
130
124
136a
120
122
126
136b
110
118
132
114
134a
135a
135b
134b
106
104

FIG. 19A

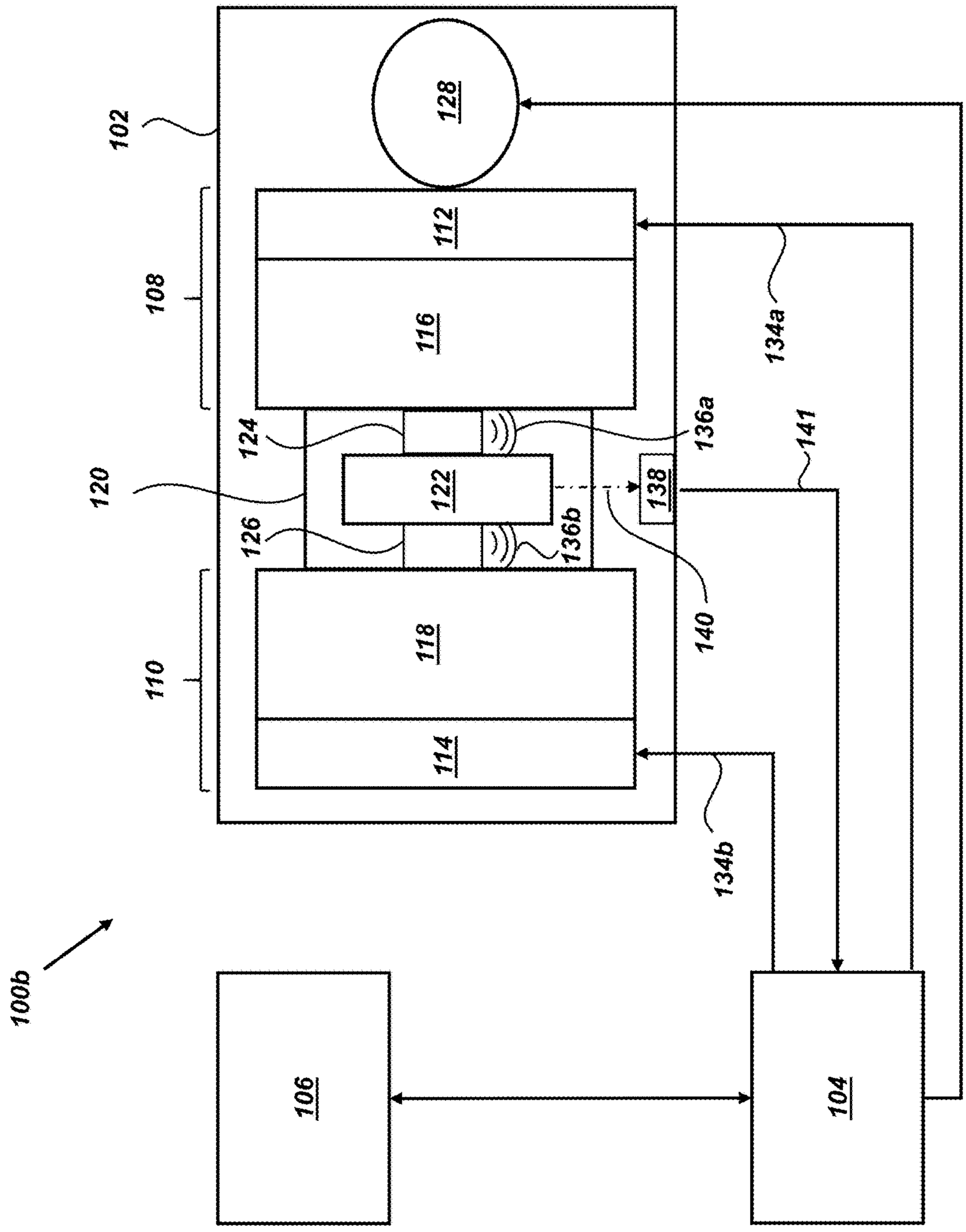

100b
102
104
106
108
110
112
114
116
118
120
122
124
126
128
134a
134b
136a
136b
138
140
141

FIG. 19B

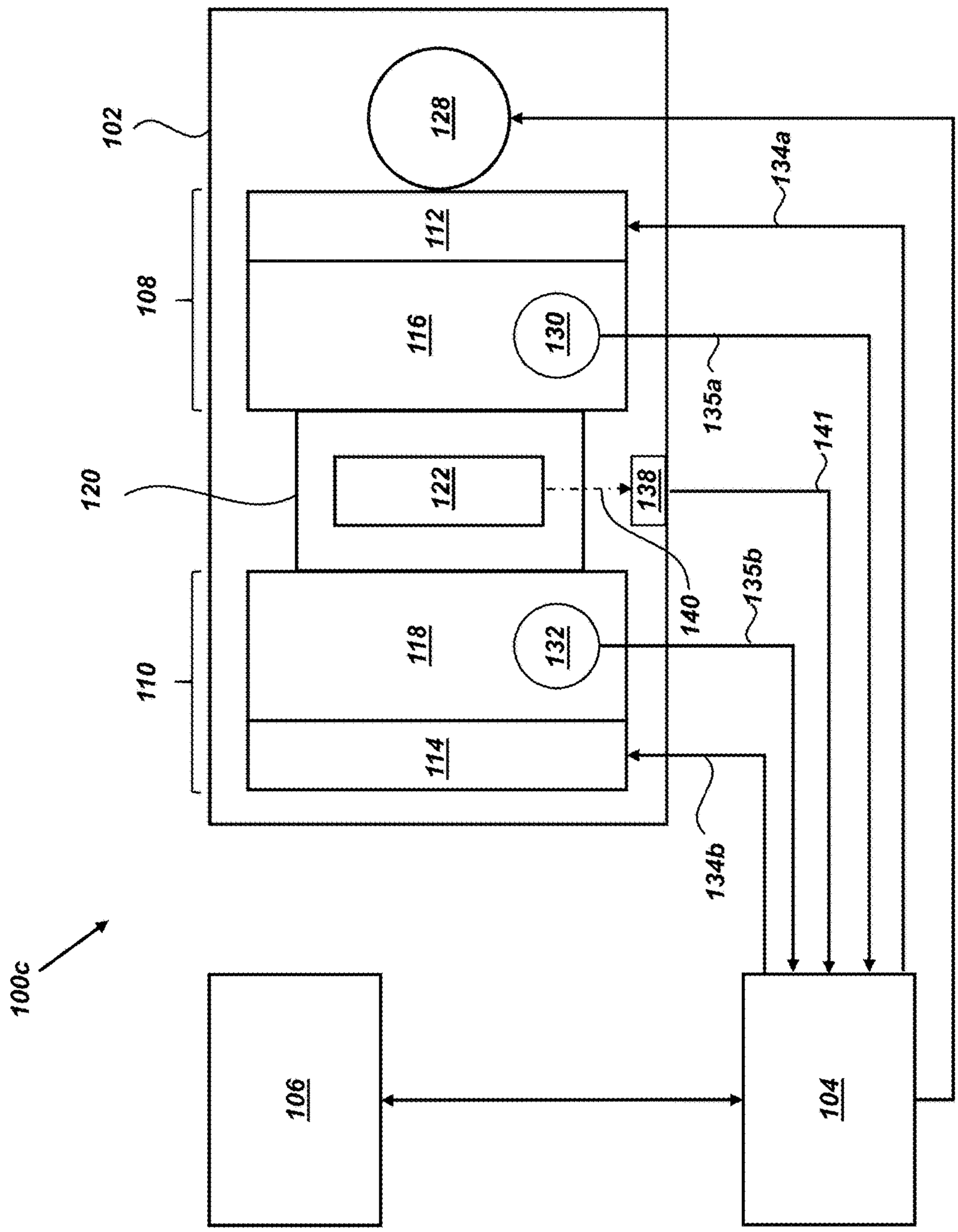

100c
102
104
106
108
110
112
114
116
118
120
122
128
130
132
134a
134b
135a
135b
138
140
141

FIG. 19C

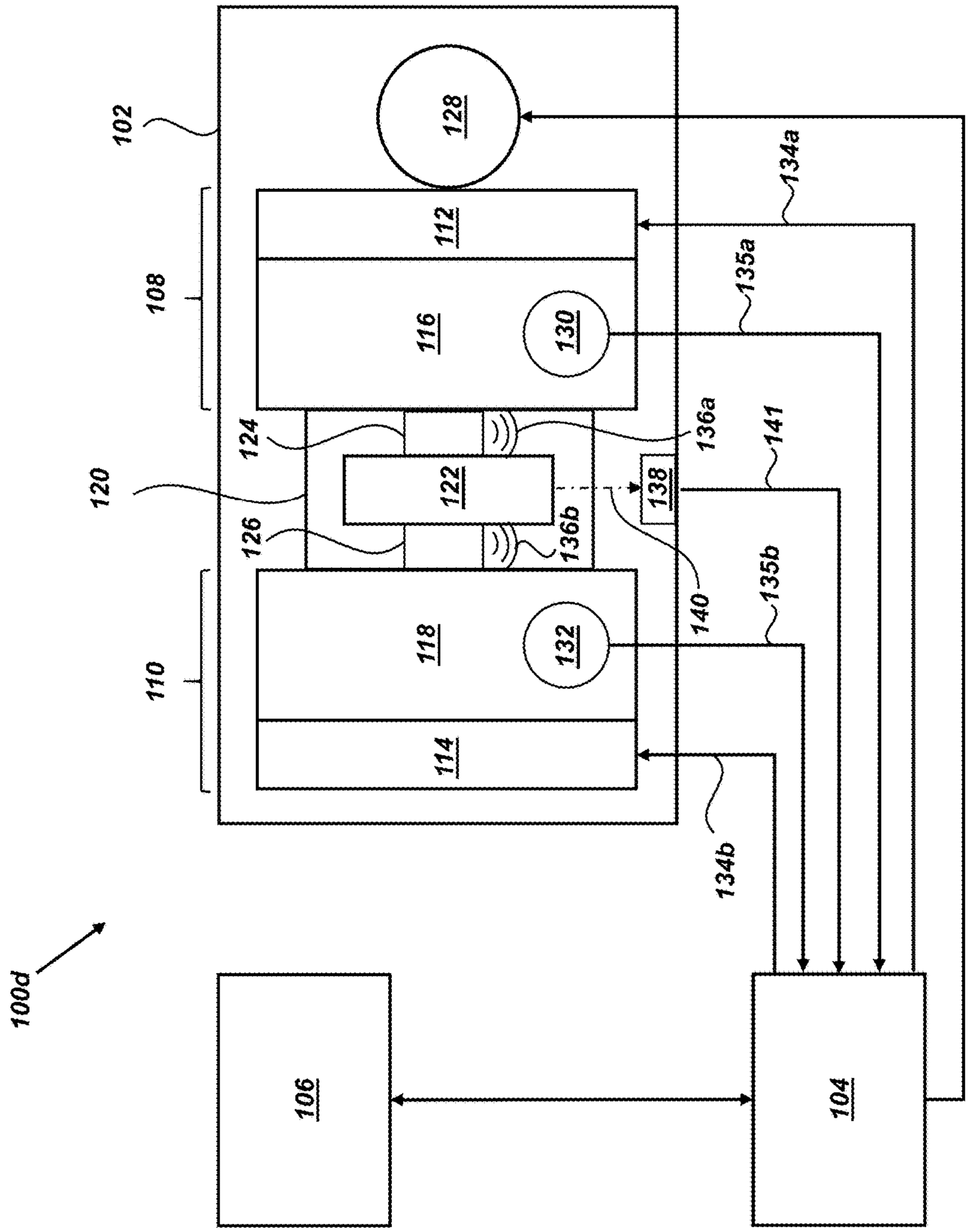

100d
102
104
106
108
110
112
114
116
118
120
122
124
126
128
130
132
134a
134b
135a
135b
136a
136b
138
140
141

FIG. 19D

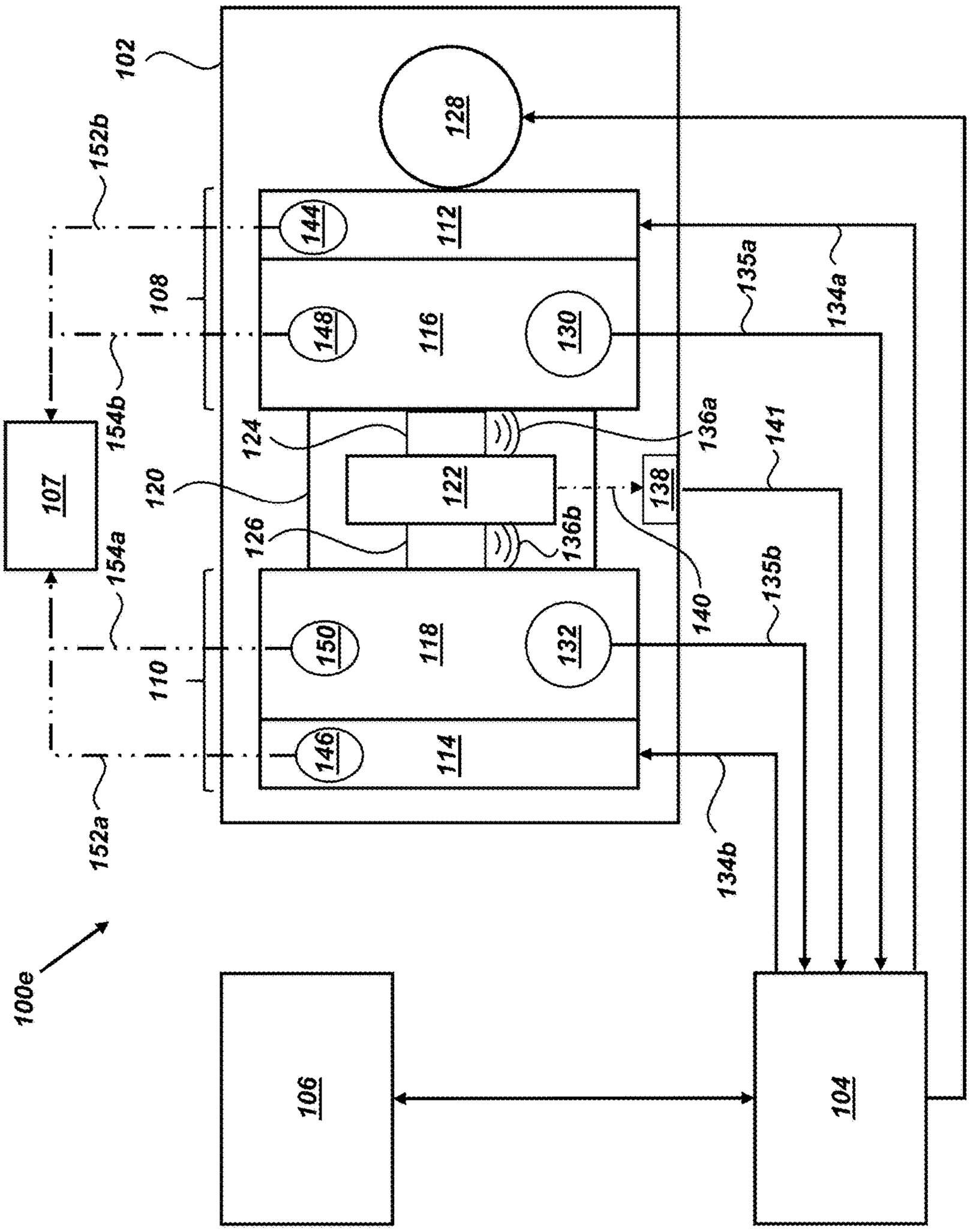

100e
102
152b
154b
154a
152a
107
108
110
120
124
126
128
122
136a
136b
138
140
141
112
116
118
114
144
148
150
146
130
132
135a
135b
134a
134b
106
104

FIG. 19E

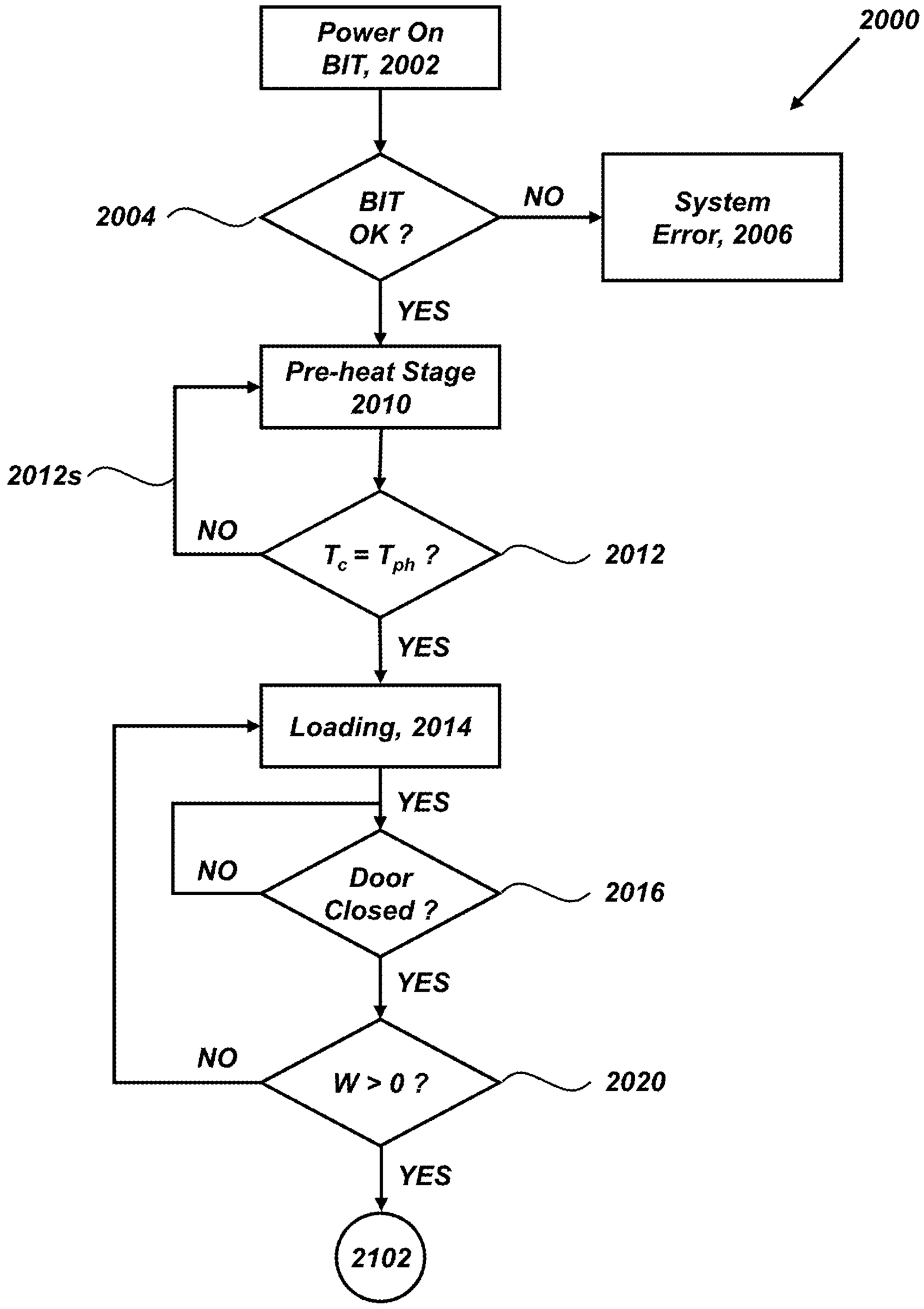

Power On
BIT, 2002
2000
2004
BIT
OK ?
NO
System
Error, 2006
YES
Pre-heat Stage
2010
2012s
NO
$T_c = T_{ph}$?
2012
YES
Loading, 2014
YES
NO
Door
Closed ?
2016
YES
NO
W > 0 ?
2020
YES
2102

FIG. 20

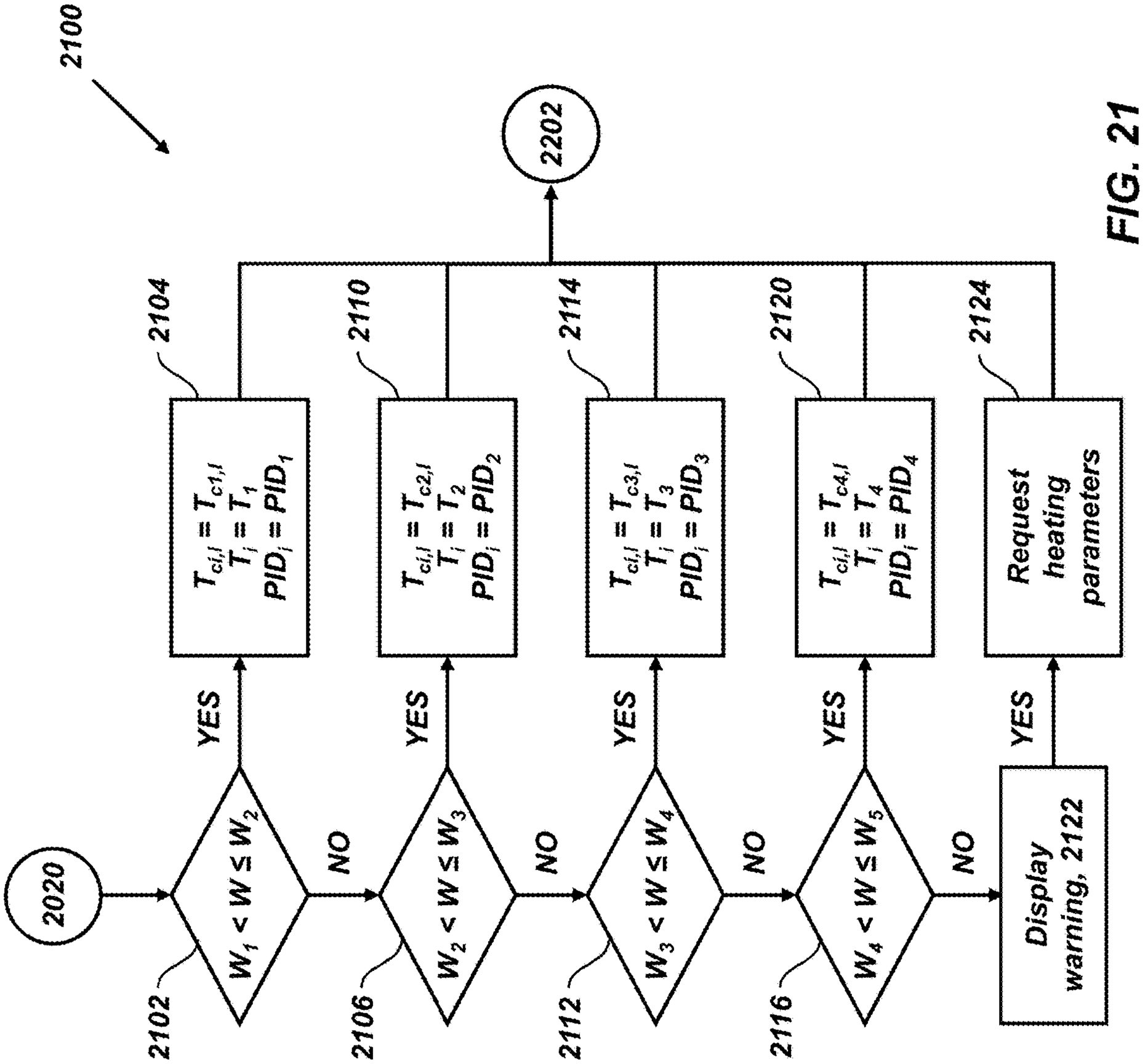

2100
2020
2102
$W_1 < W \leq W_2$
NO
2104
$T_{ci,I} = T_{c1,I}$
$T_i = T_1$
$PID_i = PID_1$
YES
2106
$W_2 < W \leq W_3$
NO
2110
$T_{ci,I} = T_{c2,I}$
$T_i = T_2$
$PID_i = PID_2$
YES
2112
$W_3 < W \leq W_4$
NO
2114
$T_{ci,I} = T_{c3,I}$
$T_i = T_3$
$PID_i = PID_3$
YES
2116
$W_4 < W \leq W_5$
NO
2120
$T_{ci,I} = T_{c4,I}$
$T_i = T_4$
$PID_i = PID_4$
YES
Display warning, 2122
2124
Request heating parameters
YES
2202

FIG. 21

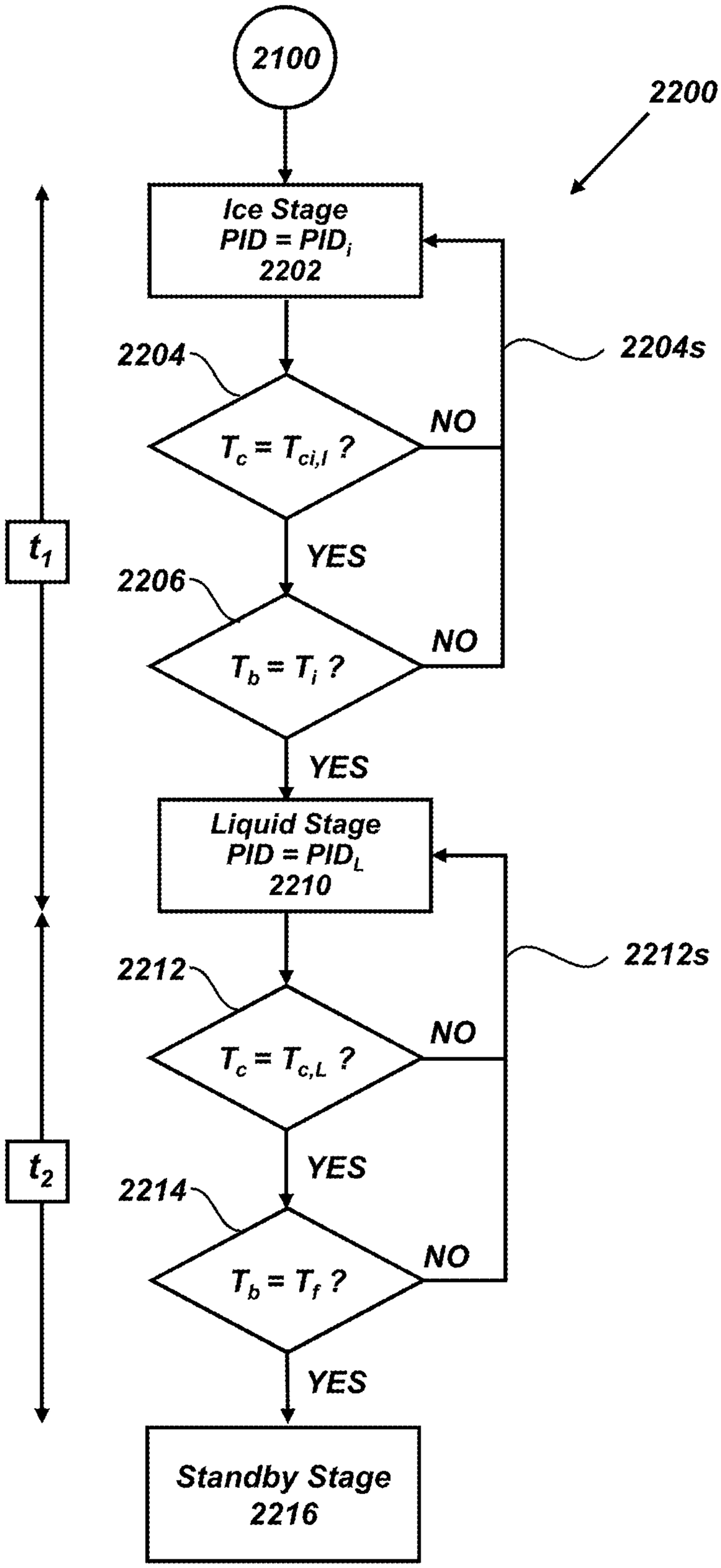

2100
2200
Ice Stage
PID = PID_i
2202
2204
2204s
T_c = T_ci,l ?
NO
YES
2206
T_b = T_i ?
NO
YES
t_1
Liquid Stage
PID = PID_L
2210
2212
2212s
T_c = T_c,L ?
NO
YES
2214
T_b = T_f ?
NO
YES
t_2
Standby Stage
2216

FIG. 22

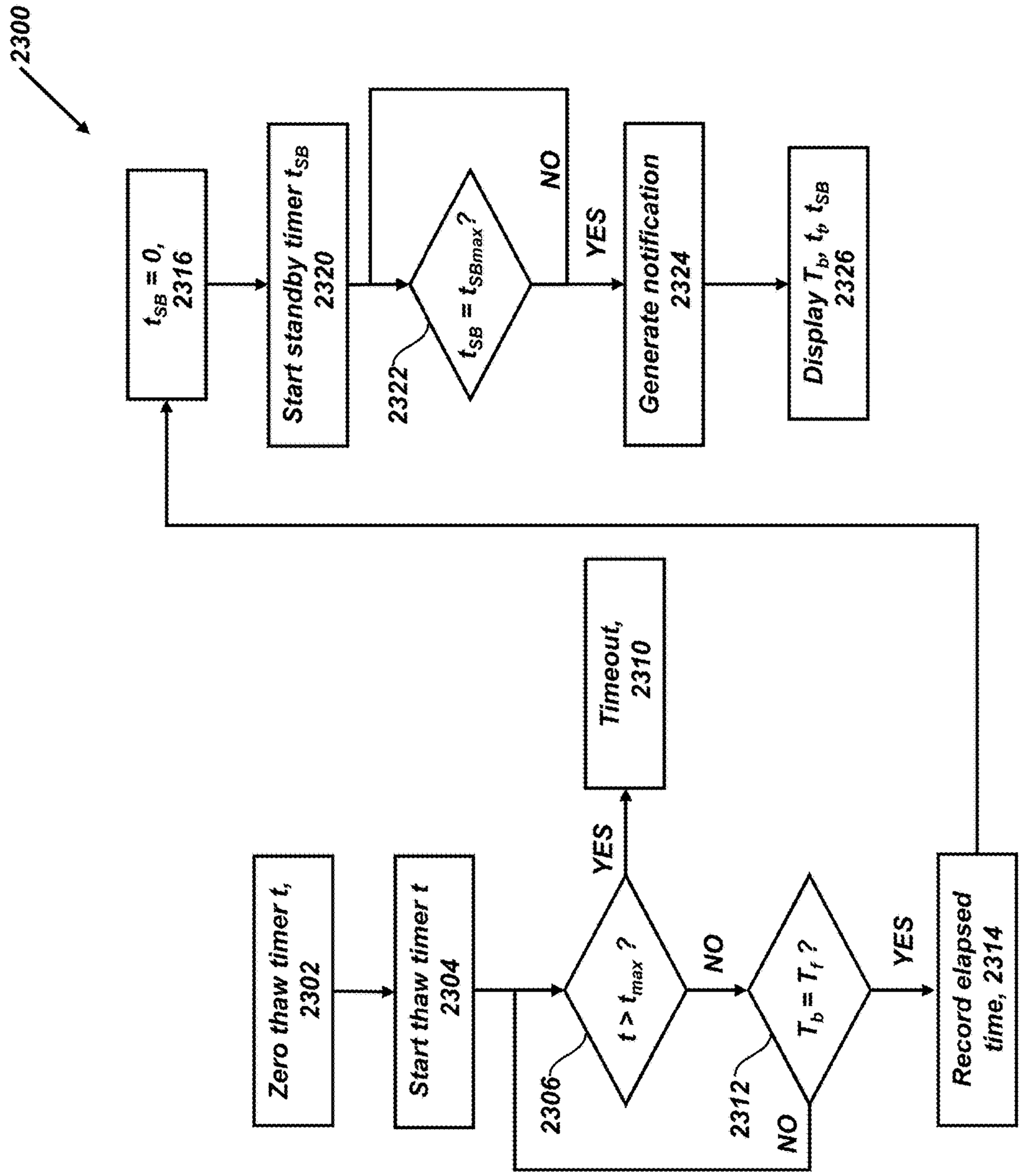
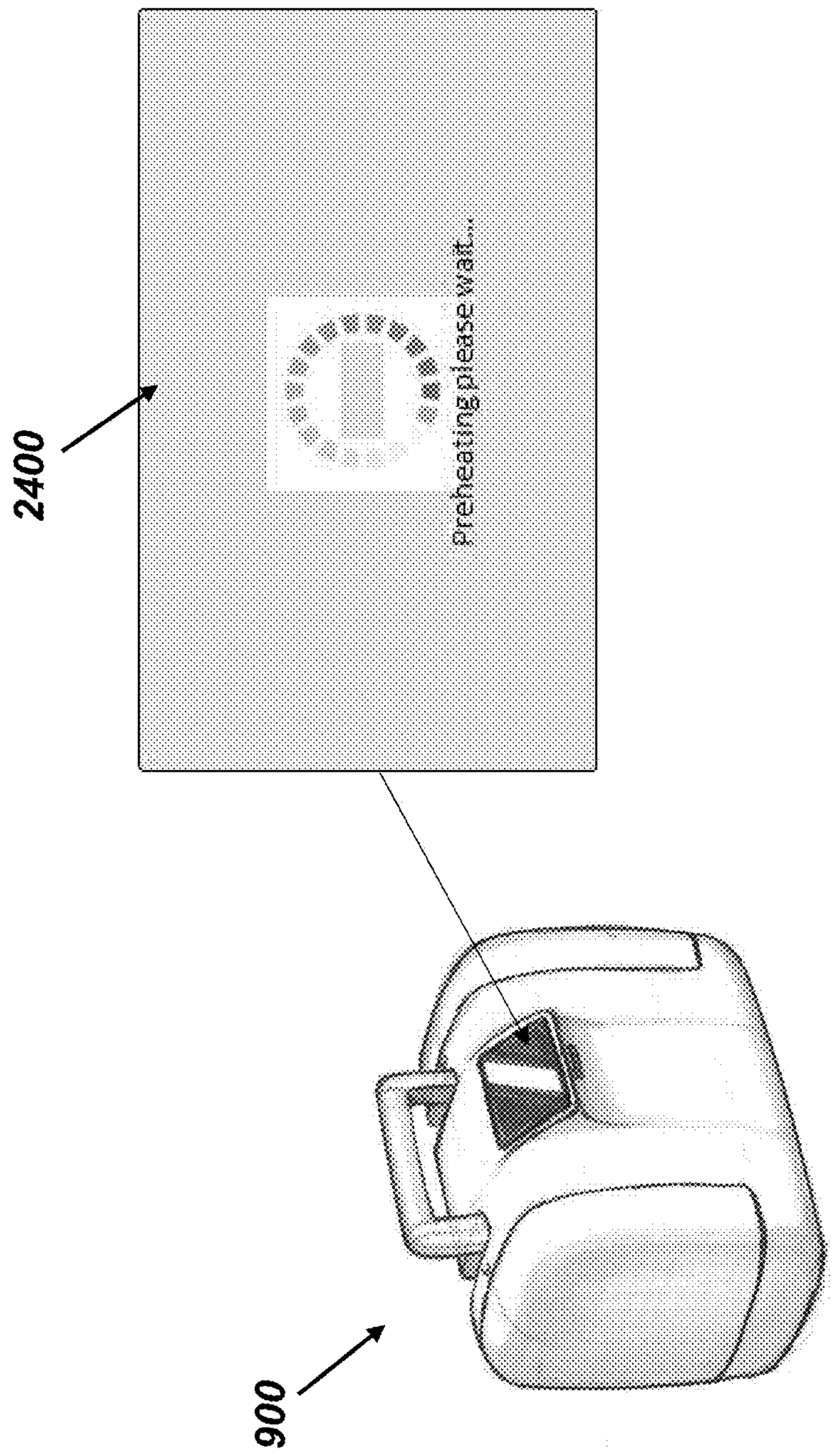

2300
Zero thaw timer t_t 2302
Start thaw timer t 2304
2306
$t > t_{max}$?
YES
Timeout, 2310
NO
2312
$T_b = T_f$?
NO
YES
Record elapsed time, 2314
$t_{SB} = 0$, 2316
Start standby timer t_{SB} 2320
2322
$t_{SB} = t_{SBmax}$?
NO
YES
Generate notification 2324
Display T_b, t_t, t_{SB} 2326

FIG. 23

FIG. 24



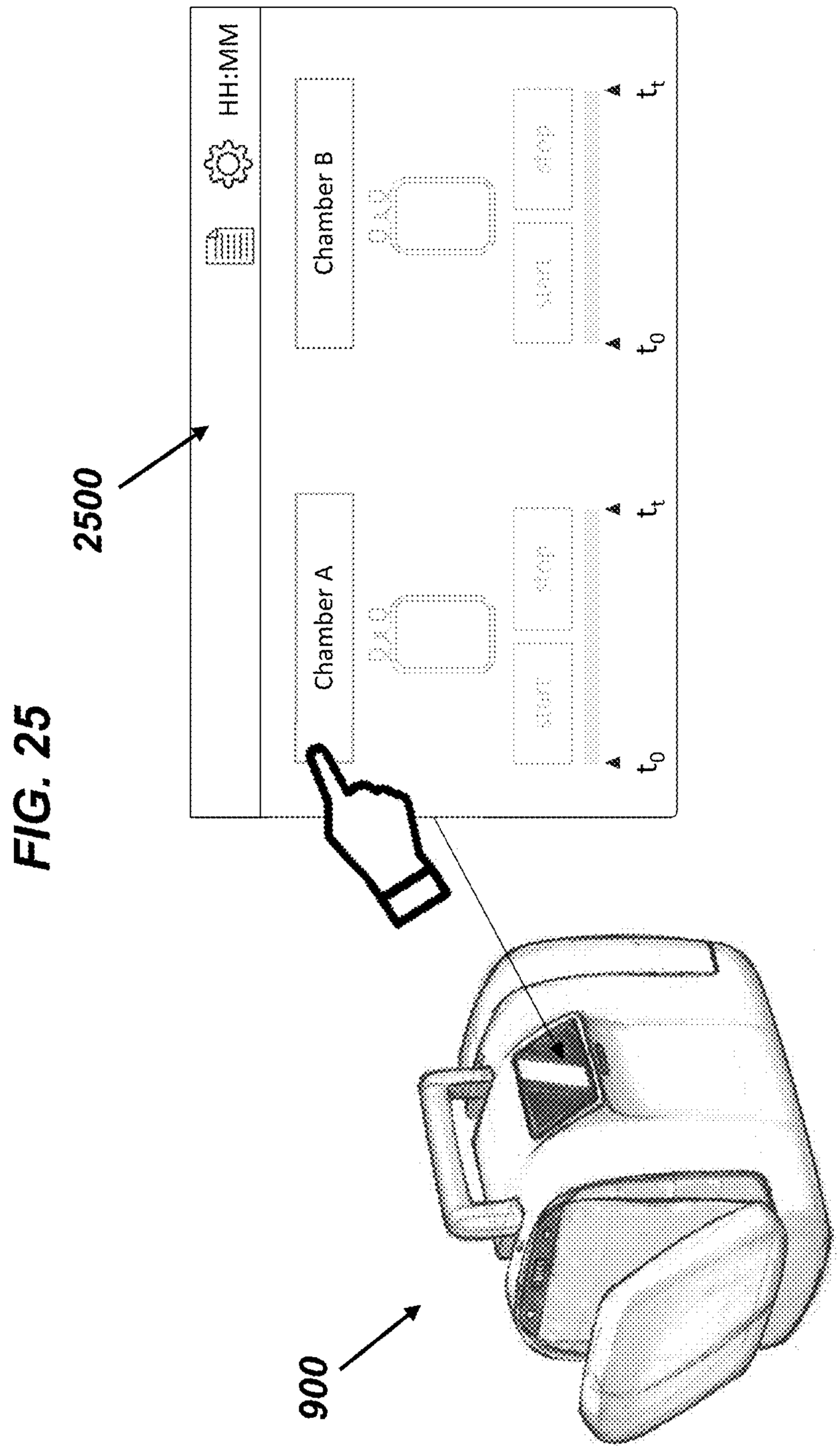


FIG. 25

FIG. 26

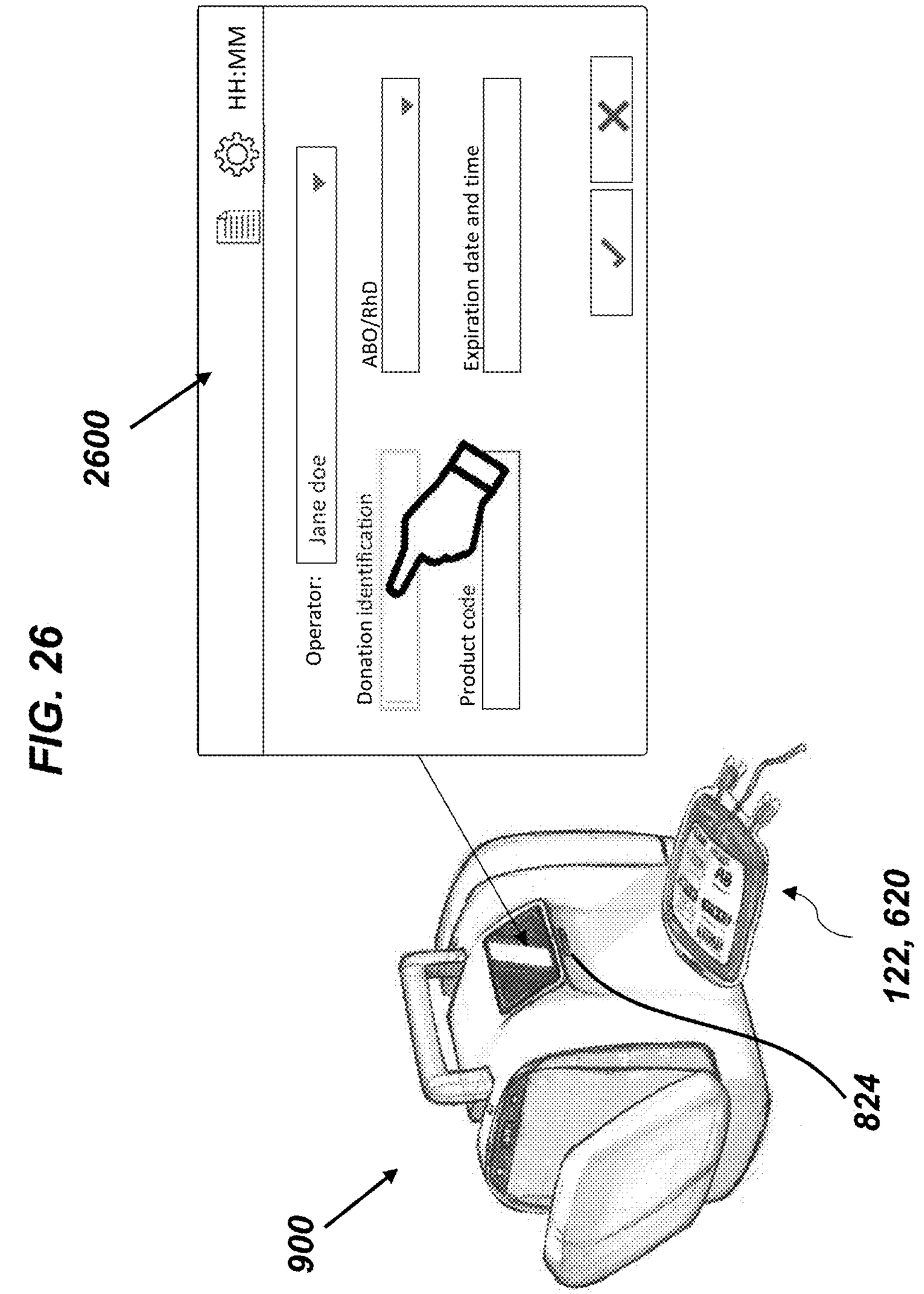

2600
HH:MM
Operator:
Jane doe
Donation identification
ABO/RhD
Product code
Expiration date and time
900
824
122, 620

FIG. 27

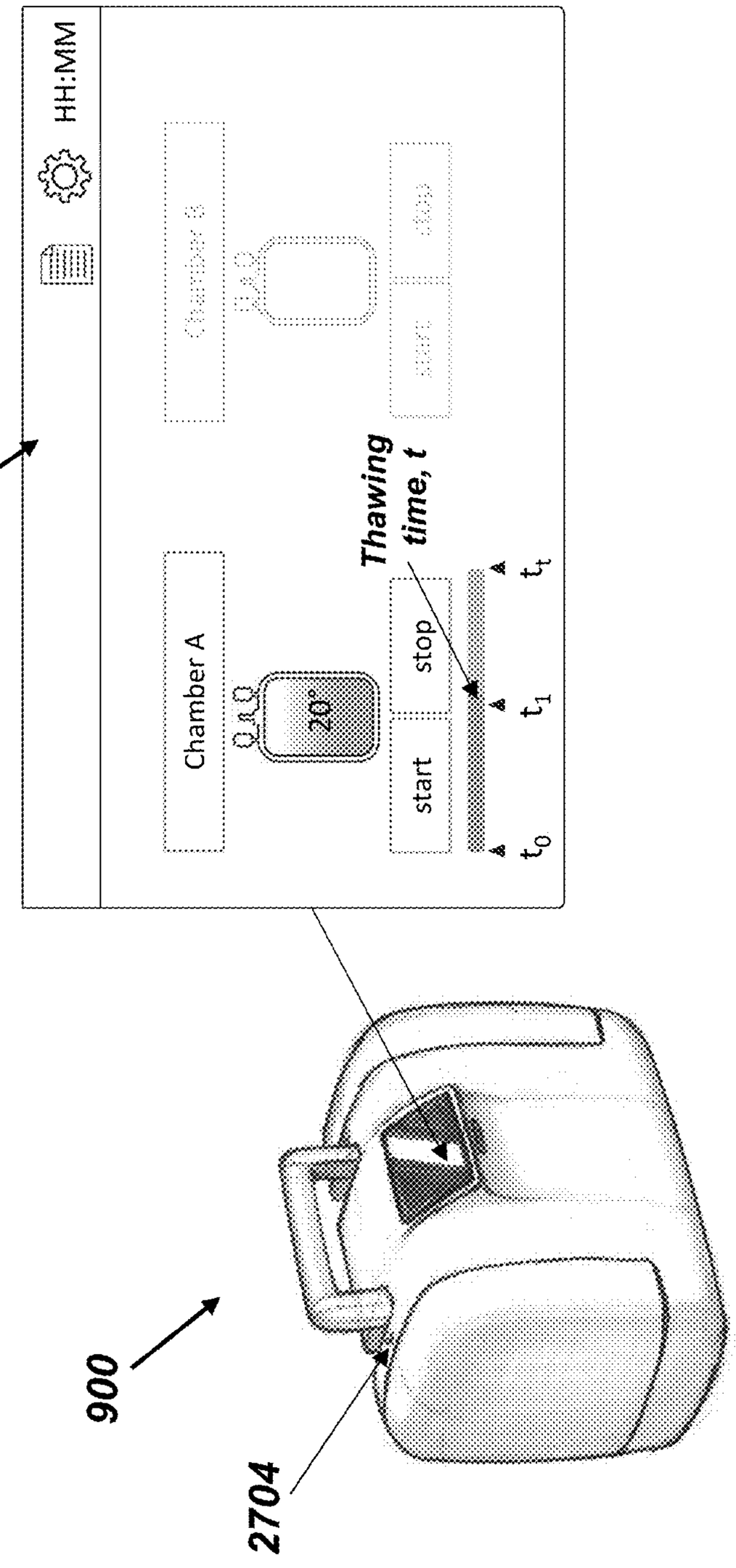

HH:MM
Chamber A
20°
stop
start
Thawing time, t
t_0
t_1
t_t
2700
900
2704

FIG. 28

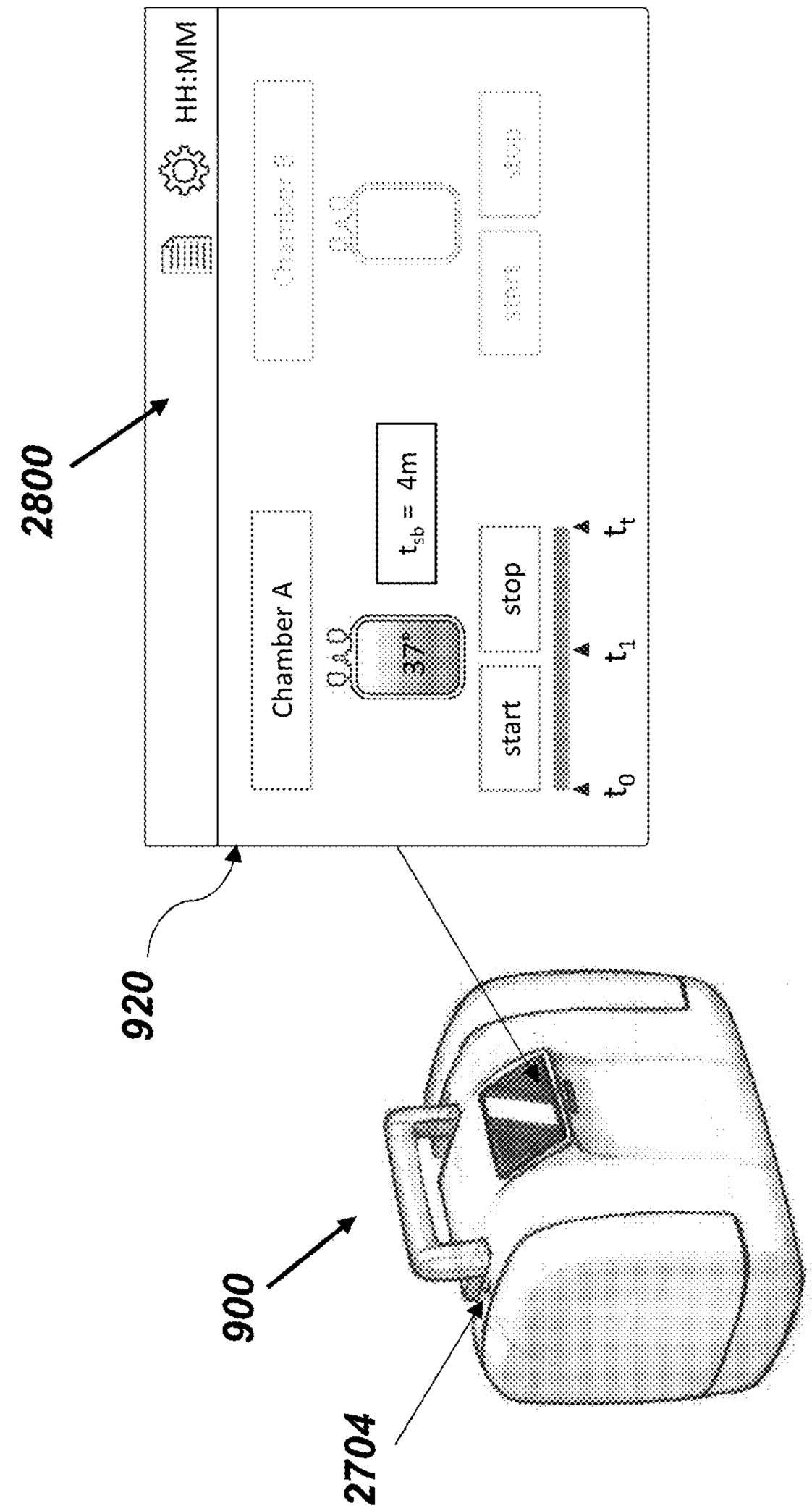
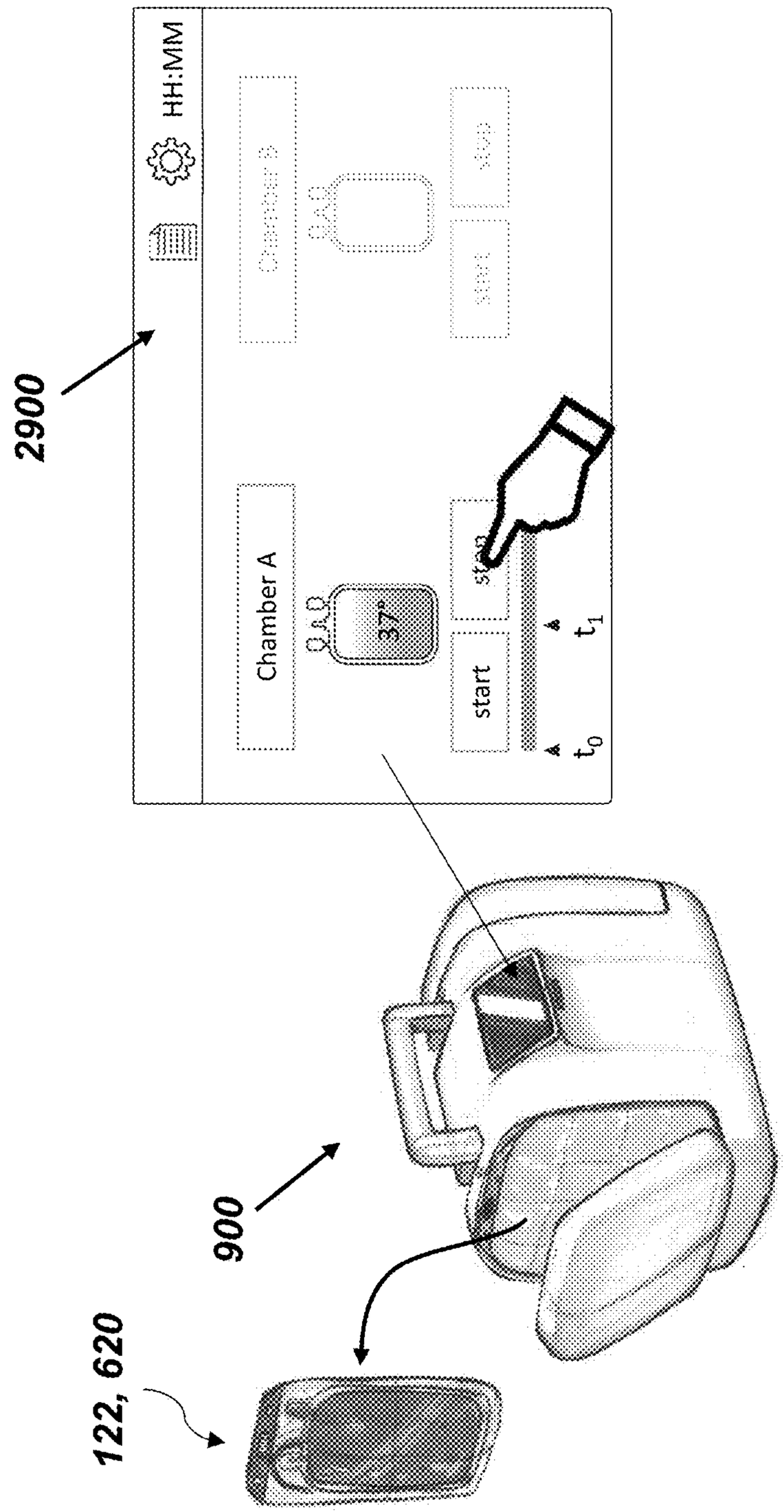

HH:MM
Chamber B
Chamber A
t_{sb} = 4m
37°
start
stop
t_0
t_1
t_t
2800
920
900
2704

FIG. 29



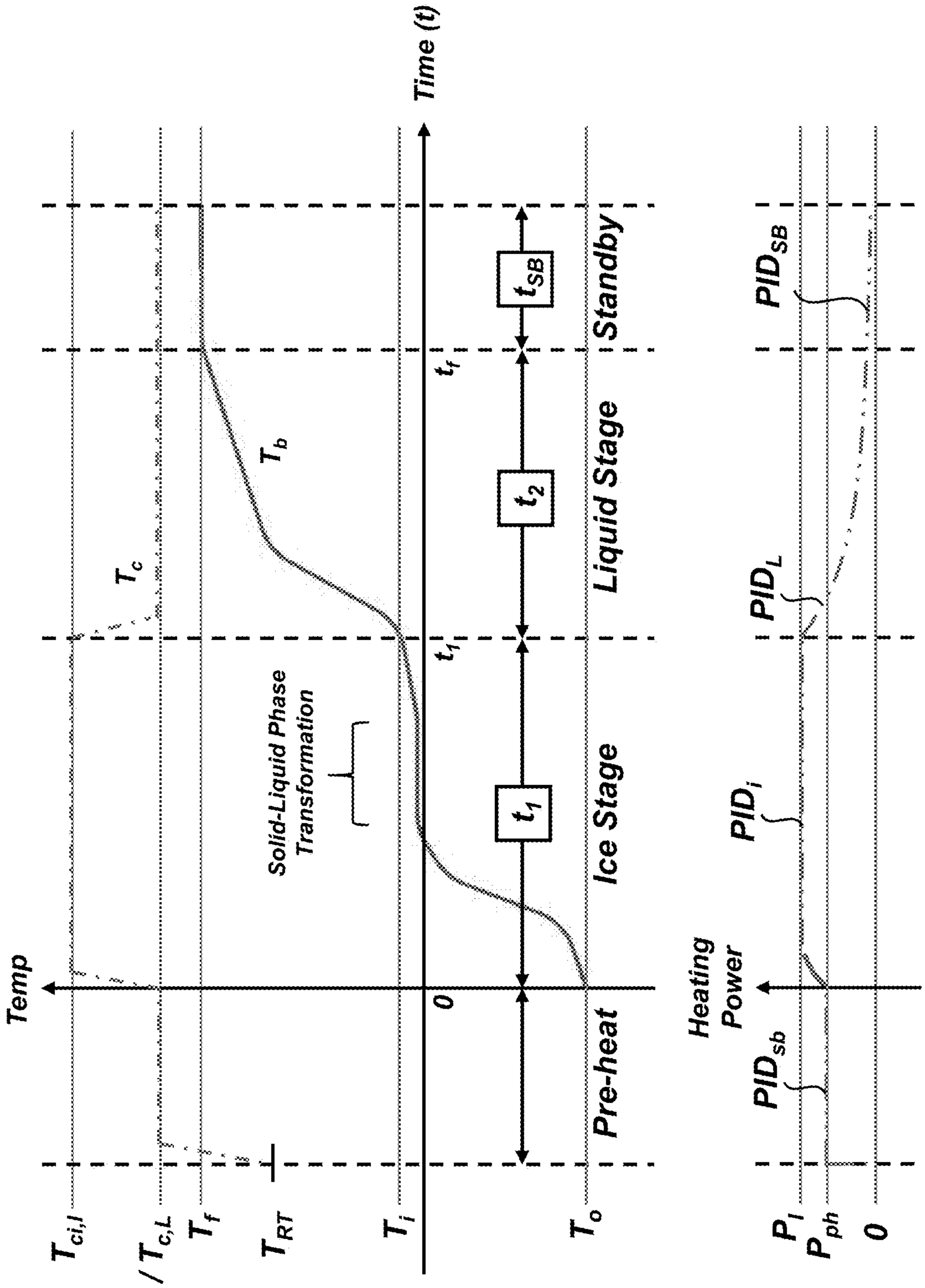

Time (t)
Temp
Heating Power
T_c
T_b
$T_{ci,I}$
T_{ph} / $T_{c,L}$
T_f
T_{RT}
T_i
T_o
t_{SB}
t_f
t_2
t_1
t_1
Standby
Liquid Stage
Ice Stage
Pre-heat
Solid-Liquid Phase Transformation
PID_{SB}
PID_L
PID_i
PID_{sb}
P_I
P_{ph}
0
0

FIG. 30

THAWING BIOLOGICAL SUBSTANCES

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to U.S. Provisional Application No. 62/668,034, filed on May 7, 2018, and entitled "Device for Thawing of Biological Substances," which is hereby incorporated by reference in its entirety.

FIELD

The present application relates to methods and devices for thawing biological substances.

BACKGROUND

Bags containing biological substances such as plasma, blood, blood products, and medication can be supplied to medical facilities for transfusion in large volume on a daily basis. These bags can be frozen, stored in inventory upon arrival, and thawed to a designated temperature just prior to transfusion.

The quality of thawed biological substances can depend upon the process by which they are thawed. Underheating a biological substance can cause patients to experience hypothermia. Conversely, overheating a biological substance can cause severe damage (e.g., denaturation) to proteins and other components that can reduce the quality of the transfused fluid, endangering patients.

Accordingly, improved methods and devices are needed to thawing biological substances.

SUMMARY

In general, methods and devices for thawing biological substances are provided.

In one embodiment, a dry thawing device is provided and includes a chamber frame configured to receive an enclosed biological substance, and a first heating assembly coupled to the chamber frame. The first heating assembly has a heater configured to be in thermal communication with an enclosed biological substance that is received within the chamber frame. The device further includes an agitation device mounted within the chamber frame and configured to cause the first heating assembly to pivot about a pivot axis relative to the chamber frame such that the first heating assembly can agitate an enclosed biological substance received within the chamber frame.

The device can have a variety of configurations. In one embodiment, first heating assembly can be linearly slidably movable relative to the chamber frame. The device can include at least one biasing element that biases the first heating assembly into contact with an enclosed biological substance that is received within the chamber frame.

In other aspects, the device can include a chamber door that is pivotally coupled to the chamber frame and that is moveable between open and closed positions. A second heating assembly can be mounted on the chamber door. The second heating assembly can have a heater that, when the chamber door is in a closed position, is configured to be in thermal communication with an enclosed biological substance that is received within the chamber frame. The first heating assembly can be configured to be positioned adjacent to a first side of an enclosed biological substance that is received within the chamber frame and the second heating assembly can be configured to be positioned adjacent to a second side of the enclosed biological substance that is opposite the first side.

In other aspects, the device can include at least one temperature sensor configured to measure a temperature of at least one of the first heating assembly and an enclosed biological substance received within the chamber frame. In another embodiment, the device can include a weight sensor configured to measure a weight of an enclosed biological substance that is received within the chamber frame. In another aspect, an overwrap bag can be disposed within the chamber frame, and the overwrap bag can contain an enclosed biological substance.

In another embodiment, a dry thawing device is provided and includes a chamber frame having a top portion, a bottom portion, and first and second opposed sidewalls coupled to the top and bottom portions. A support frame can be mounted to the bottom portion of the chamber frame and it can extend between the top and bottom portions of the chamber frame. An agitator plate can be pivotally coupled to the support frame, and the agitator plate can be configured to contact an enclosed biological substance disposed within the chamber frame. An agitation device can be mounted to the support frame and it can be configured to cause pivotal motion of the agitator plate to thereby agitate an enclosed biological substance disposed within the chamber frame.

In one aspect, the agitation device can include a cam mechanism configured to cam the agitator plate to cause pivotal motion of the agitator plate. The agitator plate can extend between the top and bottom portions of the chamber frame and can be pivotally mounted at a mid-portion thereof to the support frame.

In other aspects, the support frame can be slidably mounted to the bottom portion of the chamber frame. The support frame can be biased toward an enclosed biological substance disposed within the chamber frame to thereby bias the agitator plate toward an enclosed biological substance disposed within the chamber frame. The agitator plate can include a first heating assembly mounted thereon and configured to selectively generate thermal energy to heat an enclosed biological substance disposed within the chamber frame. In certain aspects, the agitator plate includes a top end and a bottom end, and pivotal motion of the agitator plate causes the top and bottom ends to move in opposite directions.

The device can also include a chamber door mounted to the first end of the chamber frame. The chamber door can be moveable between open and closed positions. When the chamber door is in the closed position, the chamber door and the agitator plate can define a cavity there between that is configured to receive an enclosed biological substance. A second heating assembly can be mounted on the chamber door, and the second heating assembly can have a heater that is configured to selectively generate heat to thaw an enclosed biological substance disposed within the cavity.

In another embodiment, a method for thawing a biological substance is provided and includes positioning an enclosed biological substance in a frozen state within a cavity in a housing such that the enclosed biological substance is in thermal communication with a first heating assembly located within the housing, activating the heating assembly to heat and thereby thaw the enclosed biological substance, and activating an agitation device to cause an agitator plate disposed within the housing to pivot about a pivot axis and thereby agitate the enclosed biological substance.

In certain aspects, the heating assembly can be mounted on the agitator plate such that the heating assembly pivots

within pivotal motion of the agitator plate. The agitation device can be activated while the heating assembly is activated.

In one embodiment, a dry thawing device is provided and includes a housing, a chamber frame disposed within the housing and having a base extending from a first end to a second end, and a chamber door pivotally mounted to the first end of the base and disposed at a first end of the housing. The chamber door can be movable between an open position, in which an enclosed biological substance can be inserted into a cavity within the housing, and a closed position, in which the chamber door encloses the enclosed biological substance within the cavity. A first heating assembly can be mounted on an inner surface of the chamber door such that a heater of the first heating assembly is configured to deliver thermal energy to heat an enclosed biological substance disposed within the cavity.

The device can also include a second heating assembly disposed within the housing and having a heater that is configured to selectively generate thermal energy to heat an enclosed biological substance that is received within the cavity. The first and second heating assemblies can define the cavity for receiving the enclosed biological substance there between. The second heating assembly can be mounted on an agitator plate disposed within the housing and configured to pivot about a pivot axis to agitate an enclosed biological substance disposed within the cavity. The agitator plate can be pivotally mounted to a support plate that is linearly slidably mounted on the base of the chamber frame.

The device can also include at least one temperature sensor that is configured to measure a temperature of at least one of the first heating assembly and an enclosed biological substance received within the cavity. The device can include a weight sensor that is configured to measure a weight of an enclosed biological substance that is received within the cavity. An overwrap bag can be disposed within the cavity and it can contain an enclosed biological substance.

In other aspects, the device can include a second chamber frame disposed within the housing and having a base extending from a first end to a second end, and a second chamber door pivotally mounted to the first end of the base of the second chamber frame and disposed at a second end of the housing opposite to the first end. The second chamber door can be movable between an open position, in which a second enclosed biological substance can be inserted into a second cavity within the housing, and a closed position, in which the second chamber door encloses the second enclosed biological substance within the cavity

In another embodiment, a dry thawing device is provided and includes a housing having opposed top and bottom sides, opposed front and back sides extending between the top and bottom sides, and opposed left and right sides extending between the top and bottom sides and between the front and back sides. A first chamber door is positioned on the left side of the housing and is pivotally movable between open and closed positions. The first chamber door has a first heating assembly mounted thereon and having a first heater that is configured to selectively generate thermal energy to heat a first enclosed biological substance disposed within the housing adjacent to the first chamber door. A second chamber door is positioned on the right side of the housing and is pivotally movable between open and closed positions. The second chamber door has a second heating assembly mounted thereon and having a second heater that is configured to selectively generate thermal energy to heat a second enclosed biological substance disposed within the housing adjacent to the second chamber door.

In one aspect, a first agitator plate can be disposed within the housing to define a first cavity there between with the first chamber door such. The first cavity can be configured to receive a first enclosed biological substance, and the first agitator plate can be configured to pivot to agitate the first enclosed biological substance. A second agitator plate can be disposed within the housing to define a second cavity there between with the second chamber door. The second cavity can be configured to receive a second enclosed biological substance, and the second agitator plate can be configured to pivot to agitate the second enclosed biological substance.

In other aspects, a third heating assembly can be mounted on the first agitator plate and a fourth heating assembly mounted on the second agitator plate. The third and fourth heating assemblies can each having a heater configured to selectively generate thermal energy to respectively heat first and second enclosed biological substances disposed within the housing. The first and second agitator plates with the third and fourth heating assemblies mounted thereon can be linearly slidable along the bottom side of the housing. The first and second chambers doors can be mounted adjacent to the bottom side of the housing such that an upper portion of each of the first and second chambers doors moves away from the top side of the housing to move to the open position.

In another embodiment, a method for thawing a biological substance is provided and includes pivoting a first chamber door on a first side of a housing from a closed position to an open position to provide access to a first cavity within the housing, positioning a first enclosed biological substance in a frozen state into the first cavity in the housing, pivoting the first chamber door to the closed position to cause a first heating assembly mounted on the first chamber door to contact the first enclosed biological substance, and activating the first heating assembly to cause a first heater of the first heating assembly to generate thermal energy to heat the first enclosed biological substance from the frozen state to a fluid state.

In one aspect, when the first chamber door is moved to the closed position, the first enclosed biological substance can be engaged between the first heating assembly on the first chamber door and a second heating assembly disposed within the housing. The method can further include activating the second heating assembly to cause a second heater of the second heating assembly to generate thermal energy to heat the first enclosed biological substance from the frozen state to a fluid state. The second heating assembly can be mounted on a first pivoting agitator plate, and the method can further include activating a first agitation device to cause the first pivoting agitator plate to pivot and thereby agitate the first enclosed biological substance.

In other aspects, the method can include monitoring a temperature of at least one of the first heating assembly and the first enclosed biological substance. In yet another aspect, the method can include pivoting a second chamber door on a second side of a housing from a closed position to an open position to provide access to a second cavity within the housing, and positioning a second enclosed biological substance in a frozen state into the second cavity in the housing. A third heating assembly mounted on the second chamber door can be activated to cause a third heater of the third heating assembly to generate thermal energy to heat the second enclosed biological substance from the frozen state to a fluid state.

In one embodiment, a dry thawing system is provided and includes a housing having a cavity configured to receive an enclosed biological substance, and a first heating assembly

disposed within the housing and configured to be in thermal communication with an enclosed biological substance that is received within the cavity. The first heating assembly can have a heater that is configured to selectively generate thermal energy, and a heating cushion in thermal communication with the heater. The heating cushion can be configured to conduct thermal energy generated by the heater. At least one temperature sensor can be disposed within the housing and configured to measure a temperature of at least one of the heater and the heating cushion. The at least one temperature sensor can be in communication with a power supply configured to supply electrical power to the heater, and the at least one temperature sensor can be further configured to regulate power to the heater based upon the measured temperature.

In one aspect, the at least one temperature sensor is configured to measure the temperature of the heater. When the measured temperature exceeds a predetermined threshold temperature, the at least one temperature sensor is further configured to transmit a failsafe signal to the power supply that is operative to cause the power supply to terminate delivery of power to the heater

In another aspect, the at least one temperature sensor is configured to measure the temperature of the heating cushion. When the measured temperature exceeds a predetermined threshold temperature, the at least one temperature sensor is further configured to transmit a failsafe signal to the power supply that is operative to cause the power supply to terminate delivery of power to the heater.

In one embodiment, the at least one temperature sensor can be a first temperature sensor that is configured to measure a temperature of the heater and a second temperature sensor that is configured to measure a temperature of the heating cushion. The first temperature sensor can be configured to transmit a first failsafe signal to the power supply when the measured temperature of the heater exceeds a predetermined first threshold temperature. The second temperature sensor can be configured to transmit a second failsafe signal to the power supply when the measured temperature of the heating cushion exceeds a predetermined second threshold temperature. Receipt of either of the first and second failsafe signal by the power supply is operative to cause the power supply to terminate delivery of power to the heater.

In other embodiments, the system can include the power supply. The power supply can be configured to wirelessly communicate with the at least one temperature sensor.

In another embodiment, a dry thawing system is provided and includes a housing having a cavity configured to receive an enclosed biological substance, and a first heating assembly disposed within the housing and configured to be in thermal communication with an enclosed biological substance that is received within the cavity. The first heating assembly can have a heater that is configured to selectively generate thermal energy to heat an enclosed biological substance disposed within the cavity from a frozen state to a fluid state. At least one sensor can be disposed within the housing and configured to detect at least one parameter of an enclosed biological substance that is received within the cavity. A controller can be in communication with the at least one sensor, and the controller can be configured to communicate the at least one parameter to a processor.

In one aspect, the processor can be one of a processor remote from the housing and a processor disposed within the housing. In other aspects, the at least one parameter can be at least one of a date, a geographic location, and a time. In another aspect, the at least one parameter can be data associated with a donor of a biological substance.

The at least one sensor can be configured to detect an authentication tag that is coupled to an enclosed biological substance that is received within the cavity.

In other embodiments, at least one sensor can be disposed on a chamber door pivotally mounted to the housing, and the at least one sensor can be configured to detect an authentication tag that is coupled to an enclosed biological substance that is received within the cavity.

In one embodiment, a dry thawing device is provided and includes a housing having a cavity configured to receive an enclosed biological substance, and a first heating assembly disposed within the housing and configured to be in thermal communication with an enclosed biological substance received within the cavity. The first heating assembly can have a heater that is configured to selectively generate thermal energy, and a fluid-filled cushion in thermal communication with the heater. The fluid-filled cushion can be deformable and configured to selectively transfer the thermal energy generated by the heater to an enclosed biological substance received within the cavity and in contact with the fluid-filled cushion.

In one aspect, the fluid-filled cushion includes a cushion body defining a compartment having at least one of a gel and water disposed therein.

In one embodiment, the cushion body includes an inner layer having a first surface and a second surface, with the first surface defining the compartment. The cushion body further includes a first barrier layer having a first surface and a second surface, with the first surface of the first barrier layer being disposed about at least a portion of the second surface of the inner layer, and the first barrier layer being configured to substantially prevent egress of at least one of fluid disposed in the compartment and vapor generated within the compartment. The cushion body can further include a second barrier layer that is disposed about at least a portion of the second surface of the first barrier layer such that a first portion of the second barrier layer contacts the heater and a second portion of the barrier layer contacts an enclosed biological substance received within the cavity, with the second barrier layer being configured to inhibit the inner and first barrier layers from melting.

The device can also include an agitation device disposed within the housing. The agitation device can be configured to cause the first heating assembly to pivot about a pivot axis so as to agitate an enclosed biological substance received within the cavity. At least one biasing element can bias the first heating assembly towards the cavity to cause the first heating assembly to be in thermal communication with an enclosed biological substance that is received within the cavity. The device can also include a chamber door on the housing and pivotally moveable between open and closed positions. A second heating assembly cam be coupled to the chamber door, and the second heating assembly can have a second heater that is configured to be in thermal communication with an enclosed biological substance that is received within the cavity when the chamber door is in a closed position. The second heating assembly can include a second fluid-filled cushion in thermal communication with the second heater, and the second fluid-filled cushion can be deformable and can be configured to selectively transfer the thermal energy generated by the second heater to an enclosed biological substance received within the cavity and in contact within the second fluid-filled cushion. The second fluid-filled cushion of the second heating assembly can include a cushion body having a compartment defined

therein, with the compartment of the second heating assembly having at least one of a gel and water disposed therein.

In certain aspects, the second fluid-filled cushion of the second heating assembly can include a cushion body having a compartment defined therein that is configured to hold a fluid, with the cushion body of the second heating assembly including an inner layer having a first surface and a second surface, with the first surface defining the compartment. The cushion body of the second fluid-filled cushion can also include a first barrier layer having a first surface and a second surface, with the first surface of the first barrier layer being disposed about at least a portion of the second surface of the inner layer, and the first barrier layer being configured to substantially prevent egress of at least one of fluid disposed in the compartment and vapor generated within the compartment. The cushion body of the second fluid-filled cushion can also include a second barrier layer that is disposed about at least a portion of the second surface of the first barrier layer such that a first portion of the second barrier layer contacts the heater and a second portion of the barrier layer contacts an enclosed biological substance received within the cavity, with the second barrier layer being configured to inhibit the inner and first barrier layers from melting.

In other aspects, the device can include at least one temperature sensor that is configured to measure a temperature of at least one of the first heating assembly and an enclosed biological substance received within the cavity. In another aspect, the first heating assembly and the fluid-filled cushion can be removable and replaceable.

In another embodiment, a heating assembly for heating a biological substance is provided and includes a support member a heating assembly mounted on the support member and having a heater that is configured to selectively generate thermal energy, and a fluid-filled cushion mounted on the support member and in thermal communication with the heater, with the fluid-filled cushion being deformable and configured to conduct thermal energy generated by the heater.

The fluid-filled cushion can include a cushion body defining a compartment therein, the compartment having at least one of a gel and water disposed therein. The cushion body can have an inner layer having a first surface and a second surface, with the first surface defining the compartment, a first barrier layer having a first surface and a second surface, with the first surface of the first barrier layer being disposed about at least a portion of the second surface of the inner layer, and the first barrier layer being configured to substantially prevent egress of at least one of fluid disposed in the compartment and vapor generated within the compartment, and a second barrier layer that is disposed about at least a portion of the second surface of the first barrier layer such that a first portion of the second barrier layer contacts the heater and a second portion of the barrier layer is configured to contact a substance to be heated, with the second barrier layer being configured to inhibit the inner and first barrier layers from melting.

In an embodiment, a method is provided. The method can include receiving, within a chamber frame, an enclosed biological substance. The method can also include measuring, by a first temperature sensor, a first temperature representing a temperature of a predetermined portion of at least one heating assembly. The at least one heating assembly can be in thermal communication with the enclosed biological substance received within a chamber frame. The at least one heating assembly can also be configured to selectively generate thermal energy in response to receipt of a command signal. The method can further include measuring, by a second temperature sensor, a second temperature representing a temperature of the enclosed biological substance. The method can additionally include measuring, by a weight sensor, a weight of the enclosed biological substance. The method can further include receiving, by a controller in communication with the at least one heating assembly, the first temperature, the second temperature, and the weight. The method can also include generating, by the controller, at least one command signal based upon the first temperature, the second temperature, and the weight.

In another embodiment, the controller can be configured to generate one or more first command signals according to a first operation stage when a predetermined fraction of the enclosed biological substance is solid. The controller can also be configured to generate one or more second command signals according to a second operation stage when a predetermined fraction of the enclosed biological substance is liquid.

In another embodiment, generating the one or more first command signals by the controller can include receiving a first heating assembly set point temperature for the predetermined portion of the at least one heating assembly, determining first proportional-integral-derivative (PID) settings based upon the weight of the enclosed biological substance, and generating the one or more first command signals based upon the first PID settings and a difference between the first temperature measurement and the first heating assembly set point temperature.

In another embodiment, the first heating assembly set point can be selected from the range of about 37° C. to about 42° C.

In another embodiment, generating the one or more second command signals by the controller includes receiving a second heating assembly set point temperature, different from the first heating assembly set point temperature, receiving second PID settings, different from the first PID settings, and generating the one or more second command signals based upon the second PID settings and a difference between the first temperature measurement and the second heating assembly set point temperature.

In another embodiment, the method can further include, by the controller, receiving a transition temperature set point temperature for the enclosed biological substance, and generating the one or more second command signals after determining that the second temperature is about equal to the transition temperature.

In another embodiment, the transition temperature can be selected from about 5° C. to about 8° C.

In another embodiment, the method can further include, by the controller, receiving a final temperature for the enclosed biological substance and defining an end of the second operation stage when the second temperature measurement is about equal to the final temperature.

In another embodiment, the final temperature can be selected from about 30° C. to about 37° C.

In another embodiment, the method can further include, by the controller, defining a thawing time elapsed from commencement of the first operating stage to a time prior to the end of the second operation stage, determining that the thawing time exceeds a predetermined maximum thawing time, and transmitting a command signal operative to cause the at least one heating assembly to cease generation of heat.

In another embodiment, after the end of the second operation stage, the controller can be configured to generate one or more third command signals according to a third

operation stage operative to achieve a pre-determined third heating assembly set point temperature.

In another embodiment, the method can further include, by the controller, receiving the third heating assembly set point temperature, receiving third PID settings, different from the first and second PID settings; and generating the one or more third command signals based upon the third PID settings and a difference between the first temperature measurement and the third heating assembly set point temperature

In another embodiment, the method can further include, by the controller, defining a standby time elapsed from commencement of the third operating stage, determining that the standby time exceeds a predetermined maximum standby time, and annunciating an alarm.

In another embodiment, the method can further include, by the controller, receiving a fourth heating assembly set point temperature, receiving fourth PID settings, and prior to generating the first or second command signals, generating one or more fourth command signals based upon the fourth PID settings and a difference between the first temperature measurement and the fourth heating assembly set point temperature.

In another embodiment, the fourth heating assembly set point can be selected from about 35° C. to about 40° C.

In another embodiment, the method can further include receiving the enclosed biological substance within the chamber frame after determining, by the controller, that the first temperature measurement is about equal to the fourth heating assembly set point temperature. Receiving the enclosed biological substance can include opening a chamber door pivotably mounted to a first end of a base of the chamber frame prior to the first operation stage.

In another embodiment, the method can further include, prior to measuring the weight of the enclosed biological substance, determining by the controller that the chamber door is closed.

In another embodiment, the at least one heating assembly can includes a heater configured to selectively generate the thermal energy, and a heating cushion in thermal communication with the heater and the enclosed biological substance. The first temperature can be a temperature of the heating cushion.

In another embodiment, the at least one heating assembly can include a first heating assembly and a second heating assembly. The first heating assembly can be positioned adjacent to a first side of the enclosed biological substance and the second heating assembly can be positioned adjacent to a second side of the enclosed biological substance, opposite the first heating assembly.

In another embodiment, the method can further include axially translating the first heating assembly along a base of the chamber frame to place the at least one heating assembly in thermal communication with the enclosed biological substance.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features will be more readily understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. **1**A is an exploded, front-view of one embodiment of a dry thawing chamber, illustrating a first heating assembly, a second heating assembly, a bag assembly, and an agitation device mounted to a frame;

FIG. **1**B is an exploded, rear-facing view of the dry thawing chamber of FIG. **1**A, illustrating the first heating assembly, the second heating assembly, the bag assembly, and the agitation device mounted to the frame;

FIG. **2**A is a isometric front-view of the dry thawing chamber of FIGS. **1**A-**1**B with a chamber door in a closed position;

FIG. **2**B is an isometric front view of the dry thawing chamber of FIGS. **1**A-**1**B with the chamber door pivoted to an open position;

FIG. **2**C is a side view of the dry thawing chamber of FIGS. **1**A-**1**B illustrating sliding of the chamber door in the open position;

FIG. **2**D is a side view of the dry thawing chamber of FIGS. **1**A-**1**B illustrating sliding and pivoting of the chamber door in the open position;

FIG. **3** is an exploded view illustrating the first heating assembly of the dry thawing chamber of FIGS. **1**A-**1**B;

FIG. **4** is an exploded view illustrating the second heating assembly of the dry thawing chamber of FIGS. **1**A-**1**B;

FIG. **5**A is an exploded view illustrating the bag assembly of FIGS. **1**A-**1**B;

FIG. **5**B is an isometric view illustrating the bag assembly of FIG. **5**A;

FIG. **5**C is a cross-sectional view illustrating an exemplary portion of the overwrap bag of FIGS. **5**A-**5**B configured for thermal isolation of a temperature sensor;

FIG. **6** is a front side view of an embodiment of an overwrap bag having a compartment with a first funnel configuration;

FIG. **7** is a front side view of an another embodiment of an overwrap bag having a compartment with a second funnel configuration;

FIG. **8**A is a rear-facing isometric view of the dry thawing chamber of FIGS. **1**A-**1**B illustrating the agitation device in a first position engaging the first heating assembly;

FIG. **8**B is a rear-facing isometric view of the dry thawing chamber of FIGS. **1**A-**1**B illustrating the agitation device in a second position engaging the first heating assembly;

FIG. **8**C is a side view of the dry thawing chamber of FIG. **8**A;

FIG. **8**D is a side view of the dry thawing chamber of FIG. **8**B;

FIG. **9**A is a perspective view of another embodiment of a dry thawing system including two dry thawing chambers facing a common side;

FIG. **9**B is a partially transparent perspective view of the dry thawing system of FIG. **9**A;

FIG. **10**A is a perspective view of another embodiment of a dry thawing system including two dry thawing chambers facing opposed sides;

FIG. **10**B is a partially transparent perspective view of the dry thawing system of FIG. **10**A;

FIG. **11**A is a perspective view of another embodiment of a dry thawing system including first and second dry thawing chambers, illustrating the dry thawing system in a closed configuration;

FIG. **11**B is a perspective of the dry thawing system of FIG. **11**A, illustrating the dry thawing system in an open configuration;

FIG. **11**C is a partial exploded view of a portion of the dry thawing system of FIG. **11**B, illustrating the first and second dry thawing chambers;

FIG. **12** is a partial exploded view of a first chamber door and a first heating assembly of the first dry thawing chamber of FIG. **11**C;

FIG. **13**A is a isometric view of a third heating assembly and support member of the first dry thawing chamber of FIG. **11**C;

FIG. **13**B is a partial exploded view of FIG. **13**A;

FIG. **14** is a back view of an agitation device and chassis of the first dry thawing chamber of FIG. **11**C;

FIG. **15** is an exploded view of a mounting bracket of the first dry thawing chamber of FIG. **11**C;

FIG. **16**A is side view of a portion of another embodiment of a dry thawing chamber including a support frame, illustrating the support frame in a first position;

FIG. **16**B is a side view of the portion of the dry thawing chamber of FIG. **16**A, illustrating the support frame in a second position;

FIG. **17**A is side view of a portion of another embodiment of a dry thawing chamber including an agitator plate, illustrating the agitator plate in a first position;

FIG. **17**B is a side view of the portion of the dry thawing chamber of FIG. **17**A, illustrating the agitator plate in a second position;

FIG. **18**A is a front view of an embodiment of a heating cushion;

FIG. **18**B is a cross-sectional view of the heating cushion of FIG. **18**B taken at line B-B the facing a common side;

FIG. **19**A is a schematic block diagram illustrating one exemplary embodiment of a dry thawing system including a dry thawing chamber configured to thaw a biological substance based upon temperature measurements acquired from one or more temperature sensors in a first configuration;

FIG. **19**B is a schematic block diagram illustrating another exemplary embodiment of a dry thawing system including a dry thawing chamber configured to thaw a biological substance based upon temperature measurements acquired from one or more temperature sensors in a second configuration;

FIG. **19**C is a schematic block diagram illustrating a further exemplary embodiment of a dry thawing system including a dry thawing chamber configured to thaw a biological substance based upon temperature measurements acquired from one or more temperature sensors in a third configuration;

FIG. **19**D is a schematic block diagram illustrating a further exemplary embodiment of a dry thawing system including a dry thawing chamber configured to thaw a biological substance based upon temperature measurements acquired from one or more temperature sensors in a fourth configuration;

FIG. **19**E is a schematic block diagram illustrating a further exemplary embodiment of a dry thawing system including a dry thawing chamber configured to thaw a biological substance based upon temperature measurements acquired from one or more temperature sensors in a fifth configuration;

FIG. **20** is a flow diagram illustrating one exemplary embodiment of a method for pre-heating one or more selected dry thawing chambers;

FIG. **21** is a flow diagram illustrating one exemplary embodiment of a method for determining parameters for closed-loop feedback control of heating the selected dry thawing chambers based upon a weight of the enclosed biological substance;

FIG. **22** is a flow diagram illustrating one exemplary embodiment of a method for thawing the enclosed biological substance;

FIG. **23** is a flow diagram illustrating one exemplary embodiment of a method for monitoring a thawing time and a standby time;

FIG. **24** is a diagram illustrating an exemplary embodiment of an interface for use by embodiments of the disclosed dry thawing systems during the pre-heating stage;

FIG. **25** is a diagram illustrating an exemplary embodiment of an interface for use by embodiments of the disclosed dry thawing systems to select the one or more dry thawing chambers;

FIG. **26** is a diagram illustrating an interface for use by embodiments of the disclosed dry thawing systems to input information regarding the enclosed biological substance;

FIG. **27** is a diagram illustrating an interface for use by embodiments of the disclosed dry thawing systems for monitoring a dry thawing operation;

FIG. **28** is a diagram illustrating an interface for use by embodiments of the disclosed dry thawing systems to display information regarding a completed dry thawing operation;

FIG. **29** is a diagram illustrating an interface for use by embodiments of the disclosed dry thawing systems to stop a dry thawing operation for removal of an enclosed biological substance; and

FIG. **30** is a plot illustrating exemplary embodiments of measured temperatures and heating cushion power as a function of time during a pre-heating stage, an ice stage, a liquid stage, and a standby stage.

It is noted that the drawings are not necessarily to scale. The drawings are intended to depict only typical aspects of the subject matter disclosed herein, and therefore should not be considered as limiting the scope of the disclosure.

DETAILED DESCRIPTION

Certain exemplary embodiments are described below to provide an overall understanding of the principles of the structure, function, manufacture, and use of the devices disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those skilled in the art will understand that the devices specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments and that the scope of the present invention is defined solely by the claims. The features illustrated or described in connection with one exemplary embodiment may be combined with the features of other embodiments. Such modifications and variations are intended to be included within the scope of the present invention. Further, in the present disclosure, like-named components of the embodiments generally have similar features, and thus within a particular embodiment each feature of each like-named component is not necessarily fully elaborated upon.

Existing systems for thawing enclosures containing a frozen biological substance (e.g., medication, plasma, glycerolized blood, red blood corpuscles (RBCs), etc.) operate by placing the bag in contact with heated water (e.g., water baths or water bladders). Heat is transferred from the water to the biological substance over a selected time duration to thaw the biological substance to a desired temperature range. However, these systems do not individually monitor the temperature of each bag for quality control during the thawing process. Typically, the ambient temperature of the water bath or water bladder is monitored during the thawing process. Alternatively, at best, sampled quantities of biological substances are evaluated after thawing. Thus, it can be difficult to achieve reproducible and consistent thawing of the biological substances, creating opportunities for errors that can be harmful to patients.

Accordingly, dry thawing methods and devices are provided that can receive enclosures containing biological substances and that can supply heat to thaw the biological substance without an intermediate heat conducting fluid

(e.g., water baths or water bladders). The applied heat can be dynamically controlled based upon temperature measurements acquired at or near a surface of the enclosure. Temperature measurements can also be recorded to provide a complete temperature record during the thawing process.

Embodiments are discussed herein with respect to thawing biological substances, such as medications and blood. Examples of such biological substances can include, but are not limited to, whole blood, blood products, plasma derivatives, mother's milk, ovaries, eggs, sperm, embryos, tissue, drugs, cells, such as chimeric antigen receptors t-cell (CAR-T) or other T-cells, molecular reagents, antibodies, etc.

In general, a dry thawing system can include at least one dry thawing chamber that is configured to receive an enclosed biological substance. In an exemplary embodiment, the at least one dry thawing chamber can include any one or more of a chamber frame, at least one heating assembly, an agitator device configured to agitate the enclosed biological substance, and at least one temperature sensor. The at least one heating assembly can include a heater that is configured to heat the enclosed biological substance disposed within the chamber frame. The at least one temperature sensor can be configured to monitor the temperature of the enclosed biological substance.

Dry Thawing Chamber

FIGS. **1**A-**1**B illustrate one exemplary embodiment of a dry thawing chamber **200**. As shown, the dry thawing chamber **200** includes a chamber frame **202** having a top portion **204**, a bottom portion **206**, a first sidewall **208**, and a second sidewall **210** opposite the first sidewall **208**. The first and second sidewalls **208**, **210** extend between the top portion **204** and the bottom portion **206**. A first heating assembly **400** is pivotally mounted proximate to a first end **212** (e.g., rear end) of the chamber frame **202**, about a first pivot **426**. A second heating assembly **500** is pivotally mounted to a second end **214** (e.g., front end) of the chamber frame **202**, opposite the first end **212**, about a second pivot **526**. A bag assembly **600** can be removably disposed within a cavity formed between the first heating assembly **400** and the second heating assembly **500** in order to be in thermal communication with a heater **408** of the first heating assembly **400** and a heater **508** of the second heating assembly **500**. As shown in FIGS. **1**A and **1**B, and in more detail in FIGS. **5**A-**5**C, the bag assembly **600** includes a biological substance **602** disposed within an enclosure **604** that is further disposed within an overwrap bag **606**, as will be discussed in more detail below.

The chamber frame **202** can have a variety of configurations. In the illustrated embodiment, the chamber frame **202** includes a cross-member **222** mounted to the sidewalls **208**, **210** and an agitation device **224** mounted to the cross-member **222**. As discussed below, so positioned, the agitation device **224** can contact a rear-facing surface **422** of the first heating assembly **400** to cause pivotal movement of the first heating assembly **400** about the first pivot **426**.

Optionally, the dry thawing chamber **200** can include a mechanism for estimating the weight and/or volume of the bag assembly **600**, and thus the enclosed biological substance **602**. In one embodiment, as shown in FIGS. **1**A and **1**B, the dry thawing chamber **200** includes one or more weight measuring sensors **226** (e.g., load cell[s] [LC]) for measuring a weight of the bag assembly **600**. As an example, the weight measuring sensor **226** can be provided in communication with one or more of the mounting posts **228**, **230**. Thus, when the bag assembly **600** is positioned within the dry thawing chamber **200** and supported by the mounting posts **228**, **230**, an accurate measurement of the weight of the bag assembly **600** can be obtained.

This measured weight can be transmitted to a controller for determination of the weight of the enclosed biological substance **602**. In one aspect, the controller can determine the weight of the enclosed biological substance **602**. In embodiments where the weight of the enclosure **604** and the overwrap bag **606** are negligible compared to the weight of the enclosed biological substance **602**, the measured weight can be approximately equal to the weight of the enclosed biological substance **602**. In embodiments where the weight of the enclosure **604** and the overwrap bag **606** are not negligible compared to the weight of the enclosed biological substance **602**, the controller can subtract the weights of the enclosure **604** and the overwrap bag **606** from the measured weight to obtain the weight of the enclosed biological substance **602**. The weights can be obtained by the controller from a data storage device or input by an operator of the dry thawing system using an user interface device.

Alternatively or additionally, the controller can be configured to estimate a volume of the enclosed biological substance **602** based upon the determined weight of the enclosed biological substance **602**. In one aspect, the controller can use a density of the enclosed biological substance **602** to determine the volume of the enclosed biological substance **602**. In another aspect, the controller can use a lookup table to determine the volume of the enclosed biological substance **602**. The density and/or lookup table can be obtained by the controller from a data storage device or input by an operator of the dry thawing system using an user interface device.

As indicated above, the first heating assembly **400** can be pivotably mounted to the chamber frame **202**. For example, as shown in FIGS. **1**A-**1**B, the first heating assembly **400** includes a first pivot **426**. While the first pivot **426** can have a variety of configurations, as shown, the first pivot **426** is in the form of two pivot pins each extending laterally outward from opposing sides of the first heating assembly **400**. The chamber frame **202** includes a first pivot mount **232** that is in the form of a first pivot bore extending through a first sidewall **208** of the chamber frame **202** and a second pivot bore extending through the second sidewall **210** of the chamber frame **202**. The first pivot mount **232** is configured to receive the first pivot **426**. When the first heating assembly **400** is mounted to the first pivot mount **232**, at least a portion of the first heating assembly **400** can be positioned between the first and second sidewalls **208**, **210**. So configured, the first heating assembly **400** forms a planar structure mounted proximate to the first end **212** (e.g., rear end) of the chamber frame **202**.

The location of the first pivot **426** and first pivot mount **232** can be selected along the height of the first heating assembly **400** and the chamber frame **202**. As shown, the first pivot **426** and the first pivot mount **232** are positioned at a location roughly centered along the height of the first heating assembly **400** and the first and second sidewalls **208**, **210** of the chamber frame **202**, respectively. However, alternative embodiments of the dry thawing chamber **200** can include the first pivot **426** and first pivot mount **232** at other locations, such as adjacent to the top portion **204** or bottom portion **206** of the chamber frame **202**. As discussed in greater detail below, the pivoting engagement of the first heating assembly **400** and chamber frame **202** allows the agitation device **224**, also mounted to the chamber frame **202**, to mechanically engage the first heating assembly **400** and urge it to pivot.

The second heating assembly **500** can be part of or can form the chamber door **302** and the chamber door **302** can be pivotably mounted to the chamber frame **202**. For example, the second heating assembly **500** can include a second pivot **526**. While the second pivot **526** can have a variety of configurations, as shown, the second pivot **526** is in the form of two pivot pins each extending laterally outward from opposing sides of the second heating assembly **500**. The chamber frame **202** includes a second pivot mount **238** that is in the form of a first pivot bore extending through a first sidewall **208** of the chamber frame **202** and a second pivot bore extending through the second sidewall **210** of the chamber frame **202**. The second pivot mount **238** is configured to receive the second pivot **526**.

The location of the second pivot **526** and second pivot mount **238** can be selected along the length of the second heating assembly **500** and the chamber frame **202**. As shown, the second pivot **526** and the second pivot mount **238** are positioned at locations adjacent to an end **536** (e.g., a bottom end) of the second heating assembly **500** and the bottom portion **206** of the chamber frame **202**, respectively. So configured, the second heating assembly **500** forms a planar structure mounted to a second end **214** (e.g., front end) of the chamber frame **202**, opposite the first end **212**.

As shown in FIGS. **2**A-**2**B, this configuration can allow the chamber door **302** to pivot about the second pivot **526**, denoted by arrow **311**, between an open position and a closed position. In the open position (FIG. **2**B), the upper portion of the chamber door **302** moves away from the chamber to expose a cavity **304** defined between the chamber frame **202**, the first heating assembly **400**, and the second heating assembly **500**. Thus, when the chamber door **302** is in the open position, the cavity **304** is accessible from outside of the dry thawing chamber **200** and an bag assembly **600** can be inserted between the first heating assembly **400** and second heating assembly **500**. In the closed position (FIG. **2**A), the cavity **304** becomes sealed from the exterior of the dry thawing chamber **200** (a sealed cavity). The sealed cavity can be dimensioned to accommodate the bag assembly **600** including the overwrap bag **606**, the enclosure **604**, and the enclosed biological substance **602** contained therein. Furthermore, in the closed position, the bag assembly **600** received within the sealed cavity is positioned in contact with heating cushions **404**, **504** of the first and second heating assemblies **400**, **500** and adjacent to heaters **408**, **508**, respectively.

The chamber door **302** and chamber frame **202** can include at least one latching mechanism to lock the chamber door **302** in the closed position during use. As shown in FIGS. **2**A-**2**B, the chamber door **302** and the chamber frame **202** include first and second latching mechanisms **306**, **308**. While the first and second latching mechanisms **306**, **308** can have a variety of configurations, in the illustrated embodiment the first and second latching mechanisms **306**, **308** are structurally similar and each include a latching member **310**, **312** and a receiving member **314**, **316**. As shown in FIGS. **2**A-**2**B, each latching member **310**, **312** includes a protrusion **318**, **320** extending outwardly therefrom and through a flange **319**, **321** extending outwardly from the chamber door **302**. Each receiving member **314**, **316** in the form of a flange **322**, **324** extending outwardly from the chamber frame **202** and includes a bore **326**, **328** extending therethrough. The bores **326**, **328** are configured to receive the protrusion **318**, **320** of corresponding latching members **310**, **312**. In other embodiments, other latching mechanisms can be used.

As further illustrated in FIGS. **2**C-**2**D, the chamber door **302** can be configured to linearly slide towards and away, denoted by arrow **313**, from the chamber frame **202**. As an example, the portion of the chamber frame **202** including the second pivot mount **238** can include telescoping rails (not shown) or other sliding mechanisms. By sliding the chamber door **302** away from the chamber frame **202**, as denoted by arrow **313**, alone or in combination with pivoting, as denoted by arrow **311**, additional space can be provided for inserting the bag assembly **600** within the dry thawing chamber **200**.

Heating Assembly

Each heating assembly can have a variety of configurations. FIG. **3** is an exploded, isometric view of the first heating assembly **400**. As shown, the first heating assembly **400** includes, from front to rear, a first assembly frame **402**, the heating cushion **404** with a contact temperature sensor **405** coupled thereto, a second assembly frame **406**, the heater **408**, an isolator **410**, and a cover **412**. The contact temperature sensor **405** can be similar to third contact temperature sensor **130** shown in FIGS. **19**A and **19**C-**19**E. The isolator **410** can be a generally flexible, planar structure that possesses a relatively low thermal conductivity configured to inhibit transfer of heat from the heater **408** to the cover **412**. As an example, the isolator **410** can be formed from materials such as one or more of polystyrene foam, starch-based foams, cellulose, paper, rubber, and plastic. The heater **408** can be a generally flexible, planar structure that is configured to generate heat. In certain embodiments, the heater **408** can be a resistive heater that generates heat in response to receipt of electrical current. The heating cushion **404** can include a cushion body **414** and a lip **416** extending laterally outward from an outer periphery of the cushion body **414**.

When the first heating assembly **400** is assembled, the cover **412** is coupled to the second assembly frame **406**. The heater **408** can be positioned within or adjacent to the aperture **418** of the second assembly frame **406**, with the isolator **410** interposed between the cover **412** and the heater **408**. The second assembly frame **406** is further coupled to the first assembly frame **402**. The heating cushion lip **416** can be positioned between the second assembly frame **406** and the first assembly frame **402** and secured thereto (e.g., by friction, one or more fasteners, adhesives, etc.). At least a portion of the heating cushion body **414** can extend through the aperture **420** of the first assembly frame **402**. So assembled, the cover **412** forms a generally planar, rigid rear-facing surface **422** of the first heating assembly **402**, as shown in FIG. **1**A, the cushion body **414** forms a deformable front-facing surface **424** of the first heating assembly **402**, as shown in FIG. **1**B, and heat can be conducted from the heater **408** to the exterior surface of the cushion body **414**.

The second heating assembly **500** can be formed and assembled similarly to the first heating assembly **400**. As shown in FIG. **4**, the second heating assembly **500** includes, from front to rear, the cover **512**, the isolator **510**, the heater **508**, the second assembly frame **506**, the heating cushion **504** with a contact temperature sensor **505** coupled thereto, and the first assembly frame **502**. So assembled, the cover **512** and second assembly frame **506** form a front-facing surface **524** of the second heating assembly **500** (e.g., the chamber door **302**), as shown in FIG. **1**A, while the cushion body **514** forms a deformable rear-facing surface **522** of the second heating assembly **500**, as shown in FIG. **1**B, and heat can be conducted from the heater **508** to the exterior surface of the cushion body **514**. The contact temperature sensor **505**

can be similar to fourth contact temperature sensor **132** shown in FIGS. **19**A and **19**C-**19**E.

The cushion body **414** can be formed from a material having a relatively high thermal conductivity configured to permit transfer of heat from the heater therethrough. In further embodiments, the cushion body **414** can be formed from a reversibly deformable material. As an example, the cushion body **414** can be filled with a fluid. Non-limiting examples of suitable fluids include water, gel, synthetic oils, non-synthetic oils, other heat-absorbing materials, or any combination thereof.

In other embodiments, the heating cushion can be formed of a single layer or multiple layers (e.g., two or more layers). For example, as shown in FIG. **18**A-**18**B, a heating cushion **1900** can include a multi-layered cushion body **1902** defining a compartment **1904** therein that is configured to house a fluid. In this illustrated embodiment, the multi-layered cushion body **1902** includes an inner layer **1906**, a first barrier layer **1908**, and a second barrier layer **1910**. Each layer can have a variety of thickness. In some embodiments, each layer can have a thickness from about 1 μm to 100 μm, about 1 μm to 35 μm, about 1 μm to 33 μm, about 1 μm to 20 μm, or about 10 μm to 15 μm.

The inner layer **1906** has a first surface **1906***a* and a second surface **1906***b*, in which the compartment **1904** is bounded by the first surface **1906***a*. The inner layer can formed of any suitable flexible material. Non-limiting examples of suitable flexible materials include polyethylene, other polymeric materials having multi-axis flexibility, or any combination thereof.

The first barrier layer **1908** has a first surface **1908***a* and a second surface **1908***b*. The first barrier layer **1908** is configured to substantially prevent egress of fluid disposed in the compartment **1904** and/or vapor generated within the compartment **1904** during use. In this illustrated embodiment, the first barrier layer **1908** is disposed onto the second surface **1906***b* of the inner layer **1906**. In other embodiments, the first barrier layer **1908** can be disposed onto a portion of the second surface **1906***b* of the inner layer **1906**. Non-limiting example of suitable materials for the first barrier layer include methyl aluminum oxide, and the like, and any combination thereof.

The second barrier layer **1910** is configured to inhibit the inner and first barrier layers **1906**, **1908** from melting. For example, the second barrier layer **1910** can inhibit melting of the inner and first barrier layers **1906**, **1908** in response to the generation of a hot spot or spots between the heater and the heating cushion **1900**. A hot spot or spots can be generated, for example, as a result of pressure created by a frozen enclosed biological substance, which can expand the heating cushion. As a result, this expansion can further compress the heating cushion against the heater, and thus generate a hot spot or spots at their interface. Further, the second barrier layer **1910** is configured to permit transfer of a relatively high flux of heat therethrough from a fluid disposed within the compartment **1904** of the multi-layered heating cushion body **1902**.

In this illustrated embodiment, the second barrier layer **1910** is disposed onto the second surface **1908***b* of the first barrier layer **1908** such that a first portion **1910***a* of the second barrier layer **1910** contacts a heater and a second portion **1910***b* of the second barrier layer **1910** contacts an enclosed biological substance received within a cavity formed between heating assemblies, like first and second heating assemblies **400**, **500** shown in FIGS. **1**A-**1**B and **3**-**4** or first and third heating assemblies **1208**, **1242** shown in FIGS. **11**C-**13**B. In other embodiments, the second barrier layer **1910** can be disposed onto a portion of the second surface **1908***b* of the first barrier layer **1908**.

The second barrier layer **1910** can have a melting point that is greater than the melting points of the inner and first barrier layers **1906**, **1908**. For example, in some embodiments, the second barrier layer **1910** has a melting point from about from about 80° C. to 200° C. Non-limiting examples of suitable materials for the second barrier layer **1910** include biaxially oriented polyamide (BOPA), or the like, or any combination thereof.

In certain embodiments, a multi-layered cushion body can include two laminates partially sealed, e.g. heated sealed, together. Each laminate can have an inner layer, like inner layer **1906** as shown in FIG. **18**B, a first barrier layer, like first barrier layer **1908** as shown in FIG. **18**B, and a second barrier layer, like second barrier layer **1910** as shown in FIG. **18**B. As such, a portion of the inner layers can form a compartment defined within the cushion body, and the second barrier layers can form opposing outer surfaces of the cushion body. Each laminate can have a variety of thickness. For example, in some embodiments, each laminate can have a thickness from about 1 μm to 50 μm, or from about 1 μm to 40 μm. In other embodiments, each laminate can have a thickness of about 40 μm or of about 50 μm.

Bag Assembly

The bag assembly can also have a variety of configurations, and various bags can be used with the systems and methods disclosed herein. FIGS. **5**A-**5**B illustrate one exemplary embodiment of a bag assembly **600**. As shown, the bag assembly includes a biological substance **602** disposed in the enclosure **604** which is disposed within the overwrap bag **606**. The overwrap bag **606** can be in the form of a reversibly sealable pouch dimensioned to receive the enclosure **604**. In the event that the enclosure **604** leaks or ruptures during the thawing process, the overwrap bag **606** can isolate the biological substance **602**, thereby preventing contamination of the dry thawing system.

The overwrap bag **606** can be configured to satisfy one or more functional requirements. In one aspect, the overwrap bag **606** can possess a relatively high thermal conductivity to facilitate heating of the enclosure **604** and biological substance **602** contained therein. In another aspect, the overwrap bag **606** can be configured to withstand temperatures within a predetermined temperature range (e.g., about −196° C. to about 40° C.). In a further aspect, the overwrap bag **606** can be disposable after a single use or formed from materials capable of being sterilized and reused in accordance with the requirements of domestic and/or international governing organizations and regulatory bodies. In an additional aspect, the overwrap bag **606** can be configured to provide anti-microbial properties, whether intrinsically or through the use of coatings or additives. Examples of materials forming the overwrap bag **606** can include plastics, metals, and combinations thereof.

The overwrap bag **606** can be soft, semi-rigid, or rigid and dimensioned to receive enclosures of any size. For example, as shown in FIGS. **6** and **7**, a compartment or cavity **1002**, **1102** of an overwrap bag **1000**, **1100** can be dimensioned so as to have a funnel-shaped configuration. Further, in some embodiments, an overwrap bag can include a RFID (e.g., mounted to an outer surface), such as RFID tag **601** mounted to overwrap bag **606** as shown in FIGS. **1**A-**1**B and **5**A-**5**B, RFID tag **1001** mounted to overwrap bag **1000** shown in FIG. **6**, and RFID tag **1101** mounted to overwrap bag **1100** as shown in FIG. **7**. Exemplary embodiments of RFID tags

are described in more detail in International Patent Application No. WO 2016/023034, which is hereby incorporated by reference in its entirety.

In certain embodiments, the enclosure can be a blood bag having a volume within the range from about 100 mL to about 500 mL. In other embodiments, as shown in FIG. **7**, the enclosure **1104** can be in the form of a vial, which can contain a biological substance such as blood, cells, sperm, tissue, and the like. While the volume of the vial will be dependent at least upon the dimensions of the overwrap bag, in some embodiments, the vial can have a volume in a range of about 3 mL to about 10 mL. The volume of the heating cushion (e.g., like heating cushions **404**, **504**) and/or the elastic properties (e.g., elastic modulus) of the heating cushion (e.g., like heating cushions **404**, **504**) can be configured to accommodate the shape and volume of the enclosure, regardless of size, ensuring contact between the enclosure and the heating cushions and good conduction of heat between the heating cushions and the biological substance.

The overwrap bag **606** can include an overwrap body **608** and a cover **610** attached to one end of the overwrap body **608** (e.g., a top end). The cover **610** can be configured to open and close, allowing insertion of the enclosure **604** within the overwrap body **608** when open and hermetic sealing of the overwrap body **608** when closed for protection of enclosures, like enclosure **604**, placed therein. In certain embodiments, the cover **610** can be formed from a biologically inert material, such as an epoxy. The cover **610** can further include a closure mechanism to form the hermetic seal. The closure mechanism can be embedded and/or integrally formed with the cover **610**. Examples of closure mechanisms can include interlocking grooves and ridges, reversible adhesives, magnetic-based closures, etc.

The cover **610** can be configured to engage the chamber frame **202** for support of the bag assembly **600**. As an example, the cover **610** can be formed in the shape of hooks **612**, **614** at opposed lateral ends. The hooks **612**, **614** can rest on mounting posts **228**, **230** positioned adjacent the top portion **204** of the chamber frame **202** to suspend the bag assembly **600** in place when inserted within the dry thawing chamber **200**. In certain embodiments, the overwrap bag **606** can be in the form of an overwrap bag as discussed in previously mentioned International Patent Application No. WO 2016/023034, which is incorporated herein in its entirety.

The overwrap bag **606** can be further configured to facilitate temperature measurements of the enclosed biological substance **602**. FIG. **5**C illustrates a cross-sectional view of an exemplary portion of the overwrap bag **606**, where a contact temperature sensor **620** is positioned on an inward facing surface **622** of the overwrap bag **606**. Opposing the temperature sensor **620** on an exterior facing surface **624** of the overwrap bag **606** is an encapsulated air pocket **626**. The air pocket **626** can act as an insulator, promoting thermal isolation of the temperature sensor **620** from the environment external to the overwrap bag **606**. In further embodiments, the encapsulation **628** can be formed from a material having a low thermal conductivity, further promoting thermal isolation of the temperature sensor **620**.

In further embodiments (not shown), a dry thawing chamber, like dry thawing chamber **200** shown in FIGS. **1**A-**1**B, can include a vacuum mechanism, such as a vacuum pump in fluid communication with an interior of the overwrap body (e.g., via a one-way valve). When the chamber door is placed in the closed position, the vacuum pump can be activated to remove air from the interior of the overwrap body and create a partial vacuum within the overwrap body. By reducing the pressure within the overwrap body, as compared to the ambient pressure outside the overwrap body, the overwrap body can be urged into contact with the enclosure by the ambient pressure. In this manner, the accuracy of temperature measurements acquired by temperature sensor(s) mounted to the overwrap body can be improved.

Agitator

As indicated above, an agitator can be disposed within the chamber frame for agitating an enclosed biological substance during heating. The agitator can have a variety of configurations. FIGS. **8**A-**8**D illustrate one exemplary embodiment of an agitation device **224** configured to agitate the enclosed biological substance (not shown) contained within the bag assembly **600** placed within the dry thawing chamber **200**. As shown, the agitation device **224** can be mounted to the chamber frame **202** and it can include a motor **702** and a cam **704**. The cam **704** is positioned in contact with the cover **412** of the first heating assembly **400** at a predetermined distance from the first pivot **426**. When the agitation device **224** is activated, the motor **702** causes the cam **704** to rotate and make sliding contact with the cover **412**. This contact imparts reciprocal motion to the first heating assembly **400** and causes the first heating assembly **400** to reversibly pivot about the first pivot mount **232**. That is, opposing ends (e.g., top and bottom ends) of the first heating assembly **400** can oscillate relative to the chamber frame **202**.

Because the second heating assembly **500** is fixed in place when in the closed position, the pivoting motion of the first heating assembly **400** alternates application of a compressive force against opposed ends of the bag assembly **600** (e.g., top and bottom ends) and agitates the enclosed biological substance (not shown) as it thaws. As shown in FIGS. **8**A and **8**C, when the cam **704** extends towards the first heating assembly **400**, it urges the first heating assembly **400** to pivot clockwise, towards a bottom end **520** of the second heating assembly **500**. A bag assembly **600** positioned between the first and second heating assemblies **400**, **500** thus experiences a compressive force at its bottom end that urges the enclosed biological substance (not shown) upwards. As further shown in FIGS. **8**B and **8**D, when the cam **704** retracts away from the first heating assembly **400**, the enclosed biological substance (not shown) is no longer urged towards the top portion **204** of the chamber frame **202** and moves downwards, towards the bottom portion **206** of the chamber frame **202**, under the force of gravity. In response, the first heating assembly **400** pivots counterclockwise, towards a top end **518** of the second heating assembly **500**. The bag assembly **600** positioned between the first and second heating assemblies **400**, **500** thus experiences a compressive force at its top end that further urges the enclosed biological substance (not shown) downwards.

The frequency and magnitude at which the agitation device **224** drives the first heating assembly **400** to alternate application of compressive force against opposed ends of the bag assembly **600** can be controlled by the controller (e.g., controller **104**). In one example, the RPM of the motor **702** of the agitation device **224** can be increased to increase the frequency of agitation and decreased to decrease the frequency of the agitation. In another example, the amplitude of the agitation can be related to the radius of the cam **704** of the agitation device **224**.

Housing

One or more of the aforementioned dry thawing chambers can be contained within a housing, such as a portable housing. FIGS. **9**A-**9**B illustrate a first exemplary embodi-

ment of a dry thawing system **800** including a housing or chassis **802** containing a first dry thawing chamber **804**, like dry thawing chamber **200** shown in FIGS. **1**A-**2**D and **8**A-**8**D, and a second dry thawing chamber **806**, like dry thawing chamber **200** shown in FIGS. **1**A-**2**D and **8**A-**8**D, in communication with a power supply **808**. The power supply **808** can be configured to supply power to the first and second dry thawing chambers **804**, **806**. Each of the dry thawing chambers **804**, **806** can be arranged with chamber doors **809**, **811** facing a common side of the chassis **802** (e.g., a front side **810**). A first door **812** and a second door **814** of the chassis **802** can be coupled to the chamber door **809** of the first dry thawing chamber **804** and the chamber door **811** of the second dry thawing chamber **806**, respectively, allowing an operator to insert or remove a bag assembly, like bag assembly **600** shown in FIGS. **1**A-**1**B and **5**A-**5**B, from respective dry thawing chambers. A handle **816** is also coupled to the chassis **802**, allowing the dry thawing system **800** to be easily carried. The handle **816** can be configured to fold into a recess within the chassis **802** when not being carried.

In some embodiments, an indicator light can be provided to indicate a status of a dry thawing chamber. For example, as shown in FIG. **9**A, a first indicator light **818** can be provided to indicate a status of the first dry thawing chamber **804** and a second indicator light **820** can be provided to indicate a status of the second dry thawing chamber **806**, as discussed below. Fewer (e.g., one) or more (e.g., three or more) indicator lights can be provided according to how many dry thawing chambers are contained within a dry thawing system.

The user interface **822** can be mounted to a common side (e.g. front side **810**) of the chassis **802** and it can receive power from the power supply **808**. In certain embodiments, the user interface **822** can also include a controller. In alternative embodiments, the user interface **822** can be configured to communicate with a remote controller.

The user interface **822** can, for example, be a cathode ray tube (CRT) and/or a liquid crystal display (LCD) monitor. The interaction with an operator user can, for example, be a display of information to the operator and a keyboard and a pointing device (e.g., a mouse, trackball, optical or resistive touch screen, etc.) by which the operator can provide input to the computer (e.g., interact with a user interface element). Other kinds of devices can be used to provide for interaction with an operator. Other devices can, for example, be feedback provided to the operator in any form of sensory feedback (e.g., visual feedback, auditory feedback, or tactile feedback). Input from the operator can, for example, be received in any form, including acoustic, speech, and/or tactile input.

The controller can be configured to provide commands to a heater, like heater **408** and/or heater **508** shown in FIGS. **1**A-**4**, and an agitation device, like agitation device **224** shown in FIGS. **1**A-**1**B and **8**A-**8**D, in accordance with a predetermined thawing program. The predetermined thawing program can include a target temperature-time response of at least one heating cushion, like heating cushions **404**, **504** shown in FIGS. **1**A-**4**, and an enclosed biological substance, like enclosed biological substance **602** shown in FIGS. **1**A-**1**B and **5**A-**5**B. As an example, an operator can employ the user interface device to select the predetermined thawing program from a list of predetermined thawing programs stored by a data storage device in communication with the controller.

In other embodiments, the predetermined thawing program can be selected automatically by the controller from a list of predetermined thawing programs. As an example, the predetermined thawing program can be selected by the controller based upon a volume or weight of the enclosed biological substance.

The controller can receive the volume and/or weight of the enclosed biological substance in a variety of ways. In one aspect, the controller can receive the volume and/or weight from manual input by an operator using the user interface device. In another aspect, the user interface **822** can include an input device **824**, such as a barcode reader or other automated input device (e.g., an optical character reader, a radiofrequency tag reader, etc.) and the input device can read the volume of the enclosed biological substance from markings on enclosure itself representing the volume and/or weight (e.g., a barcode, text) or a device secured to the enclosure (e.g., an RFID tag) that electronically stores data including the volume and/or weight In a further embodiment, the controller can obtain the volume and/or weight from weight measurements of the overwrap bag when positioned in the dry thawing chamber, as discussed above.

The controller can be implemented in digital electronic circuitry, in computer hardware, firmware, and/or software. The implementation can be as a computer program product. The implementation can, for example, be in a machine-readable storage device, for execution by, or to control the operation of, data processing apparatus. The implementation can, for example, be a programmable processor, a computer, and/or multiple computers.

A computer program can be written in any form of programming language, including compiled and/or interpreted languages, and the computer program can be deployed in any form, including as a stand-alone program or as a subroutine, element, and/or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site.

Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor receives instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer can include, can be operatively coupled to receive data from and/or transfer data to one or more mass storage devices for storing data (e.g., magnetic, magneto-optical disks, or optical disks).

Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices. The information carriers can, for example, be EPROM, EEPROM, flash memory devices, magnetic disks, internal hard disks, removable disks, magneto-optical disks, CD-ROM, and/or DVD-ROM disks. The processor and the memory can be supplemented by, and/or incorporated in special purpose logic circuitry.

FIGS. **10**A-**10**B illustrate a second exemplary embodiment of a dry thawing system **900** including a chassis **902** containing two dry thawing chambers **904**, **906** in communication with a power supply **908**. Each of the dry thawing chambers **904**, **906** are arranged with chamber doors **909**, **911** facing opposed sides of the chassis (e.g., left and right sides **910***a*, **910***b*). First and second doors **911**, **912** of the chassis **902** can be coupled to the first and second chamber doors **909**, **911**, respectively, allowing an operator to insert

or remove a bag assembly, like bag assembly **600** shown in FIGS. **1**A-**1**B and FIGS. **5**A-**5**B, from respective dry thawing chambers. The user interface **920** (e.g., a touch-screen display) can also be mounted to another side of the chassis **902** (e.g., a front side **910***c*), in between the two dry thawing chambers. The second dry thawing system embodiment can also include a handle **914**, indicator lights **916**, **918**, a user interface **920**, a controller similar to the first dry thawing system **800** as shown in FIGS. **9**A-**9**B.

In certain embodiments, the portable dry thawing systems **800**, **900** of FIGS. **9**A-**9**B and **10**A-**10**B can include dry thawing chambers that are removable from their respective housings. As an example, each dry thawing chamber can be received within a socket (not shown) formed within its housing. A wiring harness or electrical contacts can be positioned within the sockets and configured to reversibly mate with a corresponding wiring harness or electrical contacts of the dry thawing chamber. Power, command signals, and measured temperatures can be transmitted between the power supply, controller, and dry thawing chamber via the wiring harnesses and/or electrical contacts. So configured, dry thawing chambers can be removed from the housing for sterilization, disinfection, repair, and/or replacement.

FIGS. **11**A-**11**C illustrate another embodiment of a dry thawing system **1200** that includes a housing or chassis **1201** containing a first dry thawing chamber **1202***a* and a second dry thawing chamber **1202***b* in communication with a power supply **1226**. The chassis **1201** has a main body **1203** with first and second opposing, doors **1204** and **1206** pivotally mounted at first and second ends **1203***a*, **1203***b* thereof. A handle **1205** is also coupled to the chassis **1201**, allowing the dry thawing system **1200** to be easily carried.

The first and second doors **1204**, **1206** serve as a chamber door of the first and second dry thawing chambers **1202***a*, **1202***b* **1203***b*, respectively, thereby allowing an operator to insert or remove an enclosed biological substance from respective dry thawing chambers. Each first and second doors **1204**, **1206** has a first heating assembly **1208** and a second heating assembly **1210**, respectively, coupled thereto. Each door **1204**, **1206** is structurally similar and each first and second heating assemblies **1208**, **1210** is structurally similar, and therefore, for the sake of simplicity, the following description is with respect to the first door **1204** and the first heating assembly **1208** coupled thereto. A person skilled in the art will understand, however, that the following discussion is also applicable to the second door **1206** and the second heating assembly **1210** coupled thereto.

As shown in more detail in FIG. **12**, the first door **1204** includes an outer cover **1212** and inner cover **1214** The first heating assembly **1208** includes a heater **1216** and a heating cushion **1218** coupled thereto. While the heater **1216** can have a variety of configurations, as shown, the heater **1216** is in the form of a heater plate. At least one temperature sensor **1220** is coupled to an outer surface **1218***a* of the heating cushion **1218**, and therefore in thermal communication therewith. As such, the illustrated at least one temperature sensor **1220** is configured to measure the temperature of the heating cushion **1218** during use. While the at least one temperature sensor **1220** can have a variety of configurations, in this illustrated embodiment, the at least one temperature sensor **1220** includes two temperature sensors, a thermistor, e.g., a NTC thermistor, and a thermocouple. In certain embodiments, one of the two temperature sensors can be in communication with the power supply **1226** that is configured to supply electrical power to the heater **1216**. In such instances, when the measured temperature of the heating cushion **1218** exceeds a predetermined threshold temperature, the one of the two temperature sensors can transmit a failsafe signal to the power supply **1226** that is operative to cause the power supply **1226** upon receipt to terminate delivery of power to the heater **1216**. In other embodiments, the at least one temperature sensor **1220** can include one temperature sensor or more than two temperature sensors.

Referring back to FIG. **11**C, the first and second dry thawing chambers **1202***a*, **1202***b* contain first and second opposing chamber frames **1222**, **1224**, respectively, in which the power supply **1226** is positioned therebetween. As shown in FIG. **6**C, the first and second chamber frames **1222**, **1224** each have a base or bottom portion **1228**, **1230** and a top portion **1232**, **1234**. The first chamber frame **1222** has first and second opposing sidewalls **1236**, **1238**, extending between its base or bottom portion **1228** and top portion **1232**. The second chamber frame **1224** has a third sidewall **1240** and a fourth, opposing sidewall that is obscured in FIG. **11**C, each extending between the base or bottom portion **1230** and top portion **1234**. The first chamber frame **1222** has a third heating assembly **1242** that is pivotally mounted to a support frame **1244**. The support frame **1244** is slidably mounted to a track **1246**, which is shown in more detail in FIGS. **13**A and **13**B. While not shown, the track **1246** is fixedly mounted to the base or bottom portion **1228** of the first chamber frame **1222**. As such, the support frame **1244** is configured to slidably move relative to the first chamber frame **1222**.

Further, while obscured in FIG. **11**C, the second chamber frame **1224** includes a fourth heating assembly, a second support frame, and a second track that are structurally similar to the third heating assembly **1242**, the first support frame **1244**, and the first track **1246** and together in a similar fashion. As such, for sake of simplicity, the following description is with respect to the third heating assembly **1242**, the first support frame **1244**, and the first track **1246**, the first door **1204** and the first heating assembly **1208** coupled thereto. A person skilled in the art will understand, however, that the following discussion is also applicable to the fourth heating assembly, the second support frame, and the second track.

As shown in FIG. **11**C and in more detail in FIGS. **13**A-**13**B, the third heating assembly **1242** includes a heater **1248** and a heating cushion **1250** coupled thereto. While the heater **1248** can have a variety of configurations, as shown, the heater **1248** is in the form of a heater plate. At least one temperature sensor **1252** is coupled to an outer surface **1250***a* of the heating cushion **1250**, and therefore in thermal communication therewith. The illustrated at least one temperature sensor **1252** is configured to measure the temperature of the heating cushion **1250** during use. While the at least one temperature sensor **1252** can have a variety of configurations, in this illustrated embodiment, the at least one temperature sensor **1252** includes two temperature sensors, a thermistor, e.g., a NTC thermistor, and a thermocouple. In certain embodiments, one of the two temperature sensors can be in communication with the power supply **1226** that is configured to supply electrical power to the heater **1248**. In such instances, when the measured temperature of the heating cushion **1250** exceeds a predetermined threshold temperature, the one of the two temperature sensors can transmit a failsafe signal to the power supply **1226** that is operative to cause the power supply **1226** upon receipt to terminate delivery of power to the heater **1248**. In other

embodiments, the at least one temperature sensor **1252** can include one temperature sensor or more than two temperature sensors.

While the support frame **1244** can have a variety of configurations, as shown, the support frame **1244** includes a base **1244***a* and two support arms **1244***b*, **1244***c* extending therefrom. As shown, the support frame **1244** is mounted to the first track **1246**. While the support frame **1244** is biased in a first direction towards a first end **1246***a* of the first track **1246**, the support frame **1244** is configured to slide along the first track **1246**. That is, the support frame **1244** can slide in a second direction towards the between the first and second ends **1246***a*, **1246***b* of the first track **1246** so as to allow the first chamber frame **1222** to accommodate for different volumes of an enclosed biological substance that is to be thawed. Further, the sliding of the support frame **1244** can also allow for and maintain an effective thermal communication between the enclosed biological substance disposed between the first and third heating assemblies **1208**, **1242**.

While the support frame **1244** is biased in a first direction towards the first end of the first track **1246**, This sliding of the support frame **1244** between the first and second ends **1246***a*, **1246***b* of the first track **1246** can be accomplished in a variety of ways. For example, in this illustrated embodiment, a first biasing element **1254** and a second biasing element, obscured in FIGS. **11**C and **13**A-**13**B, are coupled between the base **1244***a* of the support frame **1244** and the first end **1246***a* of the first track **1246**. In this illustrated embodiment, the first biasing element **1254** and the second biasing element are structurally similar, and therefore for sake of simplicity, the following description is with respect to the first biasing element **1254**. A person skilled in the art will understand, however, that the following discussion is also applicable to the second biasing element.

While the first biasing element **1254** can have a variety of configurations, as shown in FIGS. **13**A and **13**B, the first biasing element **1254** is a bi-stable spring band that is wound about a drum **1256** that is housed within and connected to the base **1244***a* of the support frame **1244**. The bi-stable spring band **1254** has a first end **1254***a* that is coupled to the first end **1246***a* of the first track **1246** and a second end (obscured in FIGS. **11**C and **13**A-**13**B) that is coupled to the drum **1256**. In this way, the support frame **1244** can linearly slide along the first track **1246** between its first and second ends **1246***a*, **1246***b*, and thus relative to the first chamber frame **1222**.

FIGS. **16**A and **16**B illustrate the linear translation of the support frame **1244** relative to the first chamber frame **1222** during use. While the heating cushion **1650** in FIGS. **16**A and **16**B is different than the heating cushion **1250** shown in FIGS. **11**C and **13**A-**13**B, a person skilled in the art will appreciate that the linear sliding movement of the support frame **1244** is the same. For purposes of simplicity only, certain components are not illustrated in FIGS. **16**A and **16**B.

In use, an enclosed biological substance (not shown) is inserted into the first chamber frame **1222** between the first heating assembly **1208** (not shown) and the third heating assembly **1632**, which is similar to the third heating assembly **1242** except for the structural configuration of the heating cushion **1650**. As the chamber door **1204** is moved from an open configuration to a closed configuration, the support frame **1244** can move in a second direction (D**2**) that is opposite the first direction (D**1**) in which the support frame **1244** is biased via the bi-stable spring band **1254**. For example, the support frame **1244** can move in the second direction (D**2**) from a first position as shown in FIG. **16**A to a second position in FIG. **16**B or any other position therebetween. As such, the force being applied to the support frame **1244**, e.g., by the enclosed biological substance, the first and third heating assemblies **1208**, **1632**, and the chamber door **1204**, is sufficient to overcome the biasing force of the bi-stable spring band **1254**. This causes the bi-stable spring band **1254** to partially unwind from the drum **1256**, thereby allowing the support frame **1244** to move. As a result, the enclosed biological substance is compressed between the first and third heating assemblies **1208**, **1632**. This compression can help increase the surface contact area between the enclosed biological substance and the first and third heating assemblies **1208**, **1632**, thereby increasing the heating efficiency. In certain instances, depending on the volume of the enclosed biological substance, the insertion of the enclosed biological substance alone can cause the support frame **1244** to slide in the second direction (D**2**).

Further, during heating, as the enclosed biological substance thaws, the position of the support frame **1244** can be adjusted. That is, during heating, as the force being applied to the support frame **1244** changes, the support frame **1244** can retract towards its first position (FIG. **16**A) via the partial rewinding of the bi-stable spring band **1254** about the drum **1256**. Once the enclosed biological substance is removed from the first chamber frame **1222**, the support frame **1244** can return to its first position as shown in FIG. **16**A.

Referring back to FIGS. **13**A and **13**B, the third heating assembly **1242** is mounted to a first surface **1258***a* (e.g., front surface) of an agitator plate **1258**. The agitator plate **1258** is pivotally coupled to the support frame **1244**. While the agitator plate **1258** can be pivotally coupled to the support frame **1244** using a variety of mechanisms, in this illustrated embodiment, a first set of pivot mounts **1260***a*, **1260***b* of the agitator plate **1258** and a second set of pivot mounts **1262***a*, **1262***b* of the support frame **1244** are coupled together via pivot pins **1264**, **1266**. As a result, this pivoting engagement defines a pivot axis (PA) in which the agitator plate **1258**, and thus the third heating assembly, can pivot relative to the first chamber frame to agitate an enclosed biological substance that is contact therewith.

The pivotal motion of the agitator plate **1258**, and thus the third heating assembly **1242**, can be effected by an agitation device. For example, as shown in FIGS. **13**A and **13**B, an agitation device **1268** is coupled to the support frame **1244** and configured to selectively contact the second surface **1258***b* of the agitator plate **1258** to cause pivotal movement thereof. In this illustrated embodiment, the agitation device **1268** is coupled to a chassis **1270** that is mounted between the two support arms **1244***b*, **1244***c* of the support frame **1244**.

As shown in FIG. **14**, the agitation device **1268** includes a motor **1272** and a cam **1274**. The motor **1272** includes a rotary motor shaft **1272***a* that is coupled to the cam **1274** such that, upon actuation, the motor **1272** can cause the cam **1274** to rotate. While the cam **1274** can have a variety of configurations, in this illustrated embodiment, the cam **1274** is oblong shaped. As a result, during rotation, the cam **1274** pushes on the second surface **1258***b* of the agitator plate **1258** to causes the agitator plate **1258** to pivot about the pivot axis (PA). This pivotal motion alternates application of a compressive force against an enclosed biological substance and agitates the enclosed biological substance, e.g., during heating. As a result, substantially even heating throughout the enclosed biological substance can be effected.

FIGS. **17**A and **17**B illustrate the pivotal motion of the agitator plate **1258** relative to the first chamber frame **1222** during use. While the heating cushion **1750** in FIGS. **17**A and **17**B is different than the heating cushion **1250** shown in FIGS. **11**C and **13**A-**13**B, a person skilled in the art will appreciate that the pivotal motion of the agitator plate **1258** is the same. For purposes of simplicity only, certain components are not illustrated in FIGS. **17**A and **17**B.

In use, an enclosed biological substance (not shown) is inserted into the first chamber frame **1222** between the first heating assembly **1208** (not shown) and the third heating assembly **1732**, which is similar to the third heating assembly **1242** except for the structural configuration of the heating cushion **1750**. Once the motor **1272** is activated, the cam **1274** can rotate and come into contact with the agitator plate **1258**, thereby causing the agitator plate **1258** to pivot in a first direction, denoted by arrow D**1**, to a first pivotal position, as shown in FIG. **17**A. This causes the top end **1258***c* of the agitator plate **1258** to move towards the support frame **1244** and the bottom end **1258***d* of the agitator plate **1258** to move away from the support frame **1244**. Since the first heating assembly **1208** is fixed in place when the chamber door **1204** is closed, pivotal motion of the agitator plate **1258** in the first direction D**1** urges the enclosed biological substance upwards towards the top portion **1232** (not shown) of the first chamber frame **1222**. In some instances, this pivotal motion can also urge fluid (not shown) within the heating cushion **1750** of the third heating assembly **1732** towards a top end **1258***c* of the agitator plate **1258**. As further shown in FIG. **17**B, the agitator plate **1258** can pivot in a second direction, denoted by arrow D**2**, from the first pivotal position to a second pivotal position. Since the first heating assembly **1208** (not shown) is fixed and the cam **1274** rotates away from the agitator plate **1258**, pivotal motion of the agitator plate **1258** in the second direction D**2** is effected by downward movement of the enclosed biological substance, and in some instances, also the heating cushion fluid, under the force of gravity. As such, the pivotal motion of the agitator plate **1258** can agitate the enclosed biological substance positioned between the first and third heating assemblies **1208**, **1732**.

Referring back to FIGS. **13**A-**13**B, a mounting bracket **1276**, which is shown in more detail in FIG. **15**, having a first portion **1276***a* and a second portion **1276***b* extending therefrom. The first portion **1276***a* of the mounting bracket **1276** is coupled to and extends between the two support arms **1244***b*. The second portion **1276***b* includes a hooking mount **1278** having at least one hook **1278***a* that is configured to engage and mount an enclosed biological substance, e.g., an enclosed biological substance disposed within a bag assembly, like bag assembly **600**, within the first chamber frame **1222** and between the first and third heating assemblies **1208**, **1242**. Further, the second portion **1276***b* includes a weight sensor **1279** that is configured to measure a weight of an enclosed biological substance, e.g., an enclosed biological substance disposed within a bag assembly, like bag assembly **600**, that is engaged to the mounting bracket **1276**.

Temperature Sensors

The one or more temperature sensors can adopt a variety of configurations. In certain embodiments, as will be discussed in greater detail below, the temperature sensors can be contact temperature sensors, such as a first contact temperature sensor **124**, a second contact temperature sensor **126**, a third contact temperature sensor **130**, and a fourth contact temperature sensor **132**, as shown in FIG. **19**A, and non-contact temperature sensors, such as a first non-contact sensor **138**, as shown in FIGS. **19**B-**19**D, and combinations thereof. In one aspect, contact temperature sensors **124**, **126** can be integrated with, or secured to, the enclosed biological substance (e.g., via an inner or outer surface of an overwrap bag, discussed below) for measurement of the temperature of the enclosed biological substance. As an example, one or more contact temperature sensors **124**, **126** can be positioned on an inner surface of the overwrap bag for contact with the enclosed biological substance. In another aspect, contact temperature sensors **130**, **132** can be integrated with, or secured to, heating cushions (e.g., an inner or outer surface) for measurement of the temperature of heating cushions. In a further aspect, non-contact temperature sensors **138** can be distanced from a target (e.g., the enclosed biological substance, the overwrap bag, the heating cushion, etc.) and configured to measure temperature of at least one target. As an example, non-contact temperature sensors can measure electromagnetic radiation emitted from the enclosed biological substance (e.g., infrared radiation, dash-dot arrows).

In certain embodiments, the temperature sensors can communicate with the controller via communication links that are wired and/or wireless. As an example, one or more of the contact temperature sensors (e.g., contact temperature sensors **124**, **126**, **130**, **132** shown in FIGS. **19**A and **19**D) can be in integrated with a radiofrequency identification (RFID) tag mounted to the overwrap bag and/or the heating cushion. Mounting can include being printed on a surface, adhered to a surface by an adhesive, and the like. In further embodiments, respective temperature sensors can be a sensor of a smart label, as discussed in International Patent Application No. WO 2016/023034, filed Aug. 10, 2015, entitled "Smart Bag Used In Sensing Physiological And/Or Physical Parameters Of Bags Containing Biological Substance," the entirety of which is hereby incorporated by reference. The RFID tag can be configured to wirelessly transmit temperature measurements to a receiver in communication with the controller. While not shown, embodiments of the non-contact sensors can also be configured to communicate wirelessly with the controller.

In further embodiments, the dry thawing chamber can include at least one contact temperature sensor (e.g., contact temperature sensors **124**, **126**, **130**, **132** shown in FIGS. **19**A and **19**D) and at least one non-contact temperature sensor (e.g., non-contact temperature sensor **138** shown in FIGS. **19**B and **19**D). This configuration can improve the accuracy of temperature measurements and provide redundancy. In one example, faulty temperature sensors can be identified. For instance, temperature measurements of the enclosed biological substance acquired by the contact temperature sensors and non-contact temperature sensors can be compared to one another. If a deviation is observed between these measurements, the controller can annunciate an alarm (e.g., an audio and/or visual signal) for replacement of the faulty temperature sensor. The alarm can also include a signal transmitted to the controller that is operative to cause the controller to cease to employ the faulty temperature sensor for control of dry thawing processes. Redundancy can be further provided by having the controller employ a non-faulty temperature sensor in place of the faulty temperature sensor for control of dry thawing processes. In this manner, faulty temperature sensors can be identified and replaced, while avoiding use of inaccurate temperature measurements for control of dry thawing processes.

Dry Thawing Systems

FIGS. **19**A-**19**D illustrate exemplary embodiments of a dry thawing system **100***a*, **100***b*, **100***c*, **100***d* for thawing biological substances. Each illustrated dry thawing system

100*a*, 100*b*, 100*c*, 100*d* includes a dry thawing chamber **102**, a controller **104**, and a user interface **106**. The dry thawing chamber **102** can include one or more heating assemblies **108**, **110**, each having a heater **112**, **114** that is in thermal communication with a heating cushion **116**, **118**. One or more heating cushions **116**, **118** can be configured to be positioned in contact with an overwrap bag **120** surrounding an enclosed biological substance **122** to thereby heat the substance. The dry thawing chamber **102** can also include one or more temperature sensors for monitoring temperature of the enclosed biological substance **122**, one or more temperature sensors for monitoring temperature of the one or more heating cushions **116**, **118**, and an agitation device **128** in mechanical communication with the overwrap bag **120** (e.g., via heating assembly **108**). The controller **104** can be placed in communication with the one or more heating assemblies **108**, **110** and the one or more temperature sensors by wired communication links and/or wireless communication links and it can be configured to employ one or more of the temperature measurements for control of a dry thawing process. In this illustrated embodiment, the one or more heating assemblies **108**, **110** are in communication with the controller **104** via wired communication links **134***a*, **134***b*.

The one or more temperature sensors can adopt a variety of configurations. FIG. **19**A illustrates a first configuration of the one or more temperature sensors including one or more first temperature contact sensors **124**, **126** and one or more second contact temperature sensors **130**, **132**. In one aspect, one or more first contact temperature sensors **124**, **126** can be integrated with, or secured to, the overwrap bag **120** (e.g., secured to an inner or outer surface of the overwrap bag **120**) for measurement of the temperature of the enclosed biological substance **122**. As shown, respective ones of the one or more first contact temperature sensors **124**, **126** are positioned on opposed, inner surfaces of the overwrap bag **120** for contact with the enclosed biological substance **122**. However, in alternative embodiments, the location and number of the one or more first contact temperature sensors **124**, **126** can be varied. In one aspect, each of the one or more first contact temperature sensors **124**, **126** can be positioned on outer surfaces of the overwrap bag **120**. In another aspect, one of the one or more first contact temperature sensors **124**, **126** can be positioned on an inner surface of the overwrap bag **120** and the other of the one or more first contact temperature sensors **124**, **126** can be positioned on an outer surface of the overwrap bag **120**. In a further aspect, the one or more first contact temperature sensors **124**, **126** can be positioned on the same side of the overwrap bag **120**. In an additional aspect, fewer (e.g., **1**) or greater (e.g., three or more) first contact temperature sensors can be employed without limit.

As further shown in FIG. **19**A, the one or more second contact temperature sensors **130**, **132** can be integrated with, or secured to, heating cushions **116**, **118** (e.g., an inner or outer surface) for measurement of the temperature of thereof. As shown, respective ones of the one or more second contact temperature sensors **130**, **132** are positioned on outer surfaces of each heating cushion **116**, **118**. However, in alternative embodiments, the location and number of the one or more second contact temperature sensors **130**, **132** can be varied. In one aspect, each of the one or more second temperature sensors **130**, **132** can be positioned on inner surfaces of their corresponding heating cushions **116**, **118** for contact with the overwrap bag **120**, and thus the enclosed biological substance **122**. In another aspect, one of the one or more second contact temperature sensors **130**, **132** can be positioned on an inner surface of its corresponding heating cushion **116**, **118** and the other of the one or more second contact temperature sensors **130**, **132** can be positioned on an outer surface of its corresponding heating cushion **116**, **118**. In a further aspect, the one or more second contact temperature sensors **130**, **132** can be positioned on the same heating cushion, e.g., either heating **116** or heating cushion **118**. In a further aspect fewer (e.g., **1**) or greater (e.g., three or more) second contact temperature sensors can be employed without limit. In another aspect, the one or more second contact temperature sensors can be distributed between the heating cushions in any combination.

In further aspects, the dry thawing system can include one or more non-contact temperature sensors. The non-contact temperature sensors can be distanced from a target (e.g., the enclosed biological substance, the overwrap bag, the heating cushion, etc.) and configured to measure temperature of at least one target. As an example, non-contact temperature sensors can measure electromagnetic radiation emitted from the enclosure (e.g., infrared radiation **140**).

In certain embodiments, the one or more non-contact temperature sensors can be employed in combination with one or more contact temperature sensors, as shown in FIGS. **19**B-**19**D. In some embodiments, as shown in FIG. **19**B, the dry thawing system **100***b* includes a non-contact temperature sensor **138** employed in combination with the one or more first contact temperature sensors **126**, **124**. In other embodiments, as shown in FIG. **19**C, the dry thawing system **100***c* includes a non-contact temperature sensor **138** employed in combination with the one or more second contact temperature sensors **130**, **132**. In yet other embodiments, as shown in FIG. **19**D, the dry thawing system **100***d* includes a non-contact temperature sensor **138** employed in combination with the one or more first contact temperature sensors **124**, **126** and the one or more second contact temperature sensors **130**, **132**. In further alternative embodiments, not shown, the contact temperature sensors (e.g., one or more first contact temperature sensors **124**, **126**, and/or one or more second contact temperature sensors **130**, **132**) can be omitted and one or more non-contact temperature sensors can be employed for measuring the temperature of the enclosed biological substance, the overwrap bag, and/or the heating cushion.

In certain embodiments, the contact temperature sensors (e.g., one or more first contact temperature sensors **124**, **126** as shown in FIGS. **19**A, **19**B, and **19**D, and one or more second contact temperature sensors **130**, **132** as shown in FIGS. **19**A, **19**C, and **19**D) and the non-contact temperature sensors (e.g., non-contact temperature sensor **138** shown in FIGS. **19**B-**19**D) can communicate with the controller **104** via communication links that are wired and/or wireless. For example, as illustrated in FIGS. **19**A, **19**B, and **19**D, the one or more first contact temperature sensors **124**, **126** are in communication with the controller **104** via wireless communication links **136***a*, **136***b*; as illustrated in FIGS. **19**A, **19**C, and **19**D, the one or more second contact temperature sensors **130**, **132** are in communication with the controller **104** via wired communication links **135***a*, **135***b*; and as illustrated in FIGS. **19**B-**19**D, the non-contact temperature sensor **138** is in communication with the controller **104** via wired communication links **141**.

In some embodiments, one or more of the contact temperature sensors can be in integrated with a radiofrequency identification (RFID) tag mounted to the overwrap bag and/or the heating cushion. Mounting can include being printed on a surface, adhered to a surface by an adhesive, and the like. In further embodiments, respective temperature

sensors can be a sensor of a smart label, as discussed in International Patent Application No. WO 2016/023034, filed Aug. 10, 2015, entitled "Smart Bag Used In Sensing Physiological And/Or Physical Parameters Of Bags Containing Biological Substance," the entirety of which is hereby incorporated by reference. The RFID tag can be configured to wirelessly transmit temperature measurements to a receiver in communication with the controller. While not shown, embodiments of the non-contact temperature sensors can also be configured to communicate wirelessly with the controller.

Beneficially, use of two or more temperature sensors selected from contact temperature sensors or non-contact temperature sensors improves the accuracy of temperature measurements and provides redundancy. In one example, faulty temperature sensors can be identified. For instance, temperature measurements of the enclosed biological substance **122** acquired by two different temperature sensors (e.g., a pair of temperature sensors selected from T_1, T_2, and T') can be compared to one another. If a deviation is observed between these measurements, the controller **104** can annunciate an alarm (e.g., an audio and/or visual signal) for replacement of the faulty temperature sensor. The alarm can also include a signal transmitted to the controller **104** that is operative to cause the controller **104** to cease to employ the faulty temperature sensor for control of dry thawing processes. Redundancy can be further provided by having the controller **104** employ a non-faulty temperature sensor in place of the faulty temperature sensor for control of dry thawing processes. In this manner, faulty temperature sensors can be identified and replaced, while avoiding use of inaccurate temperature measurements for control of dry thawing processes.

Embodiments of the dry thawing system can also be configured to provide a failsafe functionality in which one or both of the heaters **112**, **114** stop generation of heat when the temperature measured by selected ones of the one or more of the heaters **112**, **114** and the heating cushions **116**, **118** exceeds predetermined threshold temperatures. As shown in the embodiment of FIG. **1**E, a dry thawing system **100***e* can include one or more first failsafe temperature sensors **144**, **146** that are configured to measure the temperature of the one or more heaters **112**, **114** during use and one or more second failsafe temperature sensors **148**, **150** that are configured to measure the temperature of the one or more heating cushions **116**, **118** during use. The one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150** can be similar to the one or more first contact temperature sensors **126**, **124** and the one or more second contact temperature sensors **130**, **132** except that the one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150** are directly coupled to a power supply **107** that supplies electrical power to the one or more heaters **112**, **114**. That is, in certain embodiments, the one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150** are not in communication with the controller **104**.

As such, the one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150** can communicate with the power supply **107** via communication links **152***a*, **152***b*, **154***a*, **154***b* that are wired and/or wireless. In this illustrated embodiment, the one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150** are in communication with the power supply **107** via wired communication links **152***a*, **152***b*, **154***a*, **154***b*.

During use, the one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150** can be configured to produce measurement signals (e.g., voltage, current, etc.) representative of their respective temperature measurements. The measurement signals can be compared to a threshold value representing the corresponding predetermined threshold temperature. If the measured temperature represented by the measurement signal is greater than the predetermined threshold temperature represented by the threshold value, a failsafe signal can be transmitted to the power supply **107**.

The failsafe signal is operative to cause the power supply **107** to terminate delivery of electrical power independently to heaters **112**, **114**. As an example, if a first failsafe signal is transmitted to the power supply **107** in response to a temperature measurement made by either one of the first failsafe temperature sensor **144** or the second failsafe temperature sensor **148**, delivery of electrical power can be terminated to heater **112**. Alternatively, if a second failsafe signal is transmitted to the power supply **107** in response to a temperature measurement made by either one of the first failsafe temperature sensor **146** or the second failsafe temperature sensor **150**, delivery of electrical power can be terminated to heater **114**.

In certain embodiments, comparison of the measurement signal to the predetermined threshold value can be performed by a logic circuit (not shown). The measurement signal represents the input to the logic circuit and the failsafe signal represents the corresponding output of the logic circuit. In an embodiment, the logic circuit can integrated with each of the one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150**.

In an exemplary embodiment, the predetermined threshold temperature value can be different for the heaters **112**, **114** and the heating cushions **116**, **118**. In one aspect, the predetermined threshold temperature for the heaters **112**, **114** can be about 105° C. In another aspect, the predetermined threshold temperature for the heating cushions **116**, **118** can be about 40° C. for embodiments of the one or more second failsafe temperature sensors **148**, **150** in the form of a thermocouple and about 40° C. to about 60° C. for embodiments of the one or more second failsafe temperature sensors **148**, **150** in the form of a thermistor (e.g., negative temperature coefficient (NTC) thermistors and positive temperature coefficient (PTC) thermistors).

Thus, the one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150** can prevent damage to the enclosed biological substance **122**, overwrap bag **120**, and/or other components of the dry thawing system **100***e*. A person skilled in the art will appreciate that, while not shown, any of the dry thawing systems **100***a*, **100***b*, **100***c*, **100***d* described above can also include one or more first failsafe temperature sensors **144**, **146** and the one or more second failsafe temperature sensors **148**, **150**.

In use, the overwrap bag **120** containing the enclosed biological substance **122** is positioned in contact with the one or more heating assemblies **108**, **110** inside the dry thawing chamber **102**. The one or more heating cushions **116**, **118** can be deformable to accommodate the shape and volume of the overwrap bag **120** and the enclosed biological substance **122**. In this manner, contact between the overwrap bag **120** and the one or more heating cushions **116**, **118** can be ensured, promoting heat transfer from the one or more heating cushion **116**, **118** to the overwrap bag **120** and the enclosed biological substance **122** contained therein.

The controller **104** can transmit first command signals to the first heating assembly **108** and the second heating assembly **110** to cause the first heater **112** and the second heater **114**, respectively, to generate heat, at least a portion of which is conducted through the first heating cushion **116** and the second heating cushion **118**, respectively, to the overwrap bag **120**, and consequently to the enclosed biological substance **122**. The temperature of a target can be measured by one or more contact temperature sensors (e.g., first contact temperature sensors **124**, **126** and/or second contact temperature sensors **130**, **132**) and/or one or more non-contact temperature sensors (e.g., non-contact temperature sensor **138**) and transmitted to the controller **104** via additional communication links. The target can be at least one of the heating cushions **116**, **118**, the overwrap bag **120**, and the enclosed biological substance **122**.

It can be appreciated that, in certain embodiments, the temperature of the overwrap bag **120** can be approximately equal to the temperature of the enclosed biological substance **122**. Accordingly, the temperature of the enclosed biological substance **122** can be referred to herein interchangeably with the temperature of the overwrap bag **120**.

The controller **104** can employ the measured temperatures as feedback for closed-loop control of the heater **112**, **114** of each of the one or more heating assemblies **108**, **110** and achievement of the predetermined temperature-time response. In certain embodiments, the controller **104** can employ the temperature of the heating cushions **116**, **118** of each of the one or more heating assemblies **108**, **110** for closed-loop feedback control of the respective heaters **112**, **114**. In alternative embodiments, the controller **104** can employ the temperature of the enclosed biological substance **122** for closed-loop feedback control of the heaters **112**, **114**. Thus, regardless of the geometry or volume of the enclosed biological substance **122**, heat applied for thawing the enclosed biological substance **122** can be controlled to avoid over-heating or under-heating the enclosed biological substance **122**.

Substantially uniform heating can be achieved by use of the agitation device **128**. The controller **104** can also transmit second command signals to the agitation device **128** to agitate the enclosed biological substance **122**. As discussed in greater detail below, the agitation device **128** can include a motor configured to drive a rotating cam. The cam can be positioned for contact with one of the heating assemblies, which is pivotably mounted within a frame. Reciprocating motion of the cam can cause one of the heating assemblies (e.g., first heating assembly **108** shown in FIGS. **19**A-**19**D) to reversibly pivot and apply compressive forces against the overwrap bag **120** and enclosed biological substance **122**. In this manner, the enclosed biological substance **122** can be urged to move during the thawing process, facilitating substantially even heating throughout the enclosed biological substance **122**.

Substantially uniform heating can include its ordinary and customary meaning understood by one of skill in the art. Substantially uniform heating can further include achieving a difference between a maximum and minimum temperature of the enclosed biological substance that is less than or equal to a predetermined temperature difference. Examples of the predetermined temperature difference can be from the range of about 0.5° C. to about 2° C.

Heating Algorithm

Embodiments of the dry thawing system **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900** can be configured to heat the enclosed biological substance **602** in four different stages: a pre-heating stage, an ice stage, a liquid stage, and a standby stage. Embodiments of flow diagrams illustrating each of the stages are illustrated in FIGS. **20**-**23**. Embodiments of interfaces generated by the user interface **822** during one or more of these stages are further presented in FIGS. **24**-**29**. Exemplary temperature set points and temperatures measured by the one or more temperature sensors **124**, **126**, **130**, **132**, **138** during the different stages are further discussed in the context of FIG. **30**.

FIG. **20** is a flow diagram illustrating one exemplary embodiment of a method **2000**, including operations **2002**-**2020**, for pre-heating one or more dry thawing chambers **200**, **804**, **806**, **904**, **906**. Pre-heating can be performed prior to commencement of the ice stage. Pre-heating can allow the selected dry thawing chamber(s) to be maintained at a predetermined idle temperature when not in use, as long as the dry thawing **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900** is powered on. Beneficially, the pre-heating stage can reduce a total time required for thawing of the enclosed biological substance **602**.

Under circumstances where the dry heating system **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900** is unpowered prior to the pre-heating stage, a power-up process can be performed prior to commencement of the pre-heating stage. Alternatively, under circumstances where the dry heating system **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900** is powered prior to the pre-heating stage, the power-up process can be omitted. In further embodiments, the pre-heating stage can be omitted and the ice stage can begin following the power-up process.

As shown in FIG. **24**, a user can employ an interface **2400** displayed by the user interface **822** to initiate power up and pre-heating of one or more selected dry thawing chambers **200**, **804**, **800**, **904**, **906**. In operation **2002** of FIG. **20**, turning on power to the dry thawing system **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900** can activate a built in self-test (BIT) of one or more components of the dry thawing system **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900**. As an example, the BIT can include power on self-test (POST) of computing components, such as the controller **104**, as well as communication links **134***a*, **134***b*, **135***a*, **135***b*, **136***a*, **136***b*, **141**, **146***a*, **146***b* and respective self-test routines of one or more of the heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732**, agitation devices **224**, **1268**, temperature sensors **124**, **126**, **130**, **132**, **138**, weight sensor **1279**. In operation **2004**, the controller **104** determines if any component (including itself) returns a signal indicating failure of its self-test (BIT OK?). If any component returns a signal indicating failure of its self-test, BIT OK is NO, the method **2000** moves to operation **2006** and an error message is displayed by the user interface **822**. If no component returns a signal indicating failure of its self-test, BIT OK is YES, the method **2000** moves to operation **2010** to commence the pre-heat stage.

In operation **2010**, an available dry thawing chamber **200**, **804**, **800**, **904**, **906** is selected. As an example, FIG. **25** illustrates an interface **2500** displayed by the user interface **822** allowing an operator to select one or more of the dry thawing chambers **200**, **804**, **800**, **904**, **906** (e.g., chamber A and/or chamber B) for pre-heating. After input of the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** is received, the method **2000** moves to operation **2012**.

In operation **2012**, the controller **104** generates one or more command signals **2012***s* operative to control power delivered to the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** in thermal communication with the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** (e.g., the chamber frame **202**, **1222**, **1224**) to effect the temperature of respective heating cushions **116**, **118**, **1250**, **1650**, **1750** of the one or more heating assemblies **108**, **110**,

400, **500**, **1208**, **1242**, **1732**. As an example, the controller **104** is configured to perform closed-loop control of the heating cushion temperature. In one aspect, the controller **104** receives control parameters including a measured cushion temperature T_c for at least one of the heating cushions **116**, **118**, **1250**, **1650**, **1750** (e.g., from the one or more temperature sensors **124**, **126**, **130**, **132**, **138**), a pre-heating temperature set point temperature T_{ph}, and pre-heating settings PID_{ph} (proportional-integral-derivative).

In order to generate the command signals **2012***s*, the controller **104** determines if there is a difference between each received measured cushion temperature T_c and the pre-heating set point temperature T_{ph} (T_c=T_{ph}?). If the controller **104** determines that there is a difference between the measured cushion temperature T_c and the pre-heating set point temperature T_{ph} (T_c=T_{ph} is NO), a correction is calculated based upon this difference and PID_{ph}. The correction is transmitted from the controller **104** to respective ones of the heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** as the command signal(s) **2012***s* and the method **2100** returns to operation **2010**. In operation **2010**, the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** generate heat in response to receipt of the command signal(s) **2012***s*. Subsequently, the method **2000** moves to operation **2012** to again determine if there is a difference between each measured cushion temperature T_c and the pre-heating set point temperature T_{ph}. The operations **2010** and **2012** are repeated in sequence until the measured cushion temperature T_c is about equal to the pre-heating set point temperature T_{ph} (T_c=T_{ph} is YES). Subsequently, the method **2100** can move to operation **2014**.

The pre-heating parameters T_{ph} and the PID_{ph} can be independently received by the controller **104** in in a variety of ways. In one aspect, these pre-heating parameters can be input by the operator via the user interface **822**. In another aspect, these pre-heating parameters can be retrieved from a memory. In a further aspect, these pre-heating parameters can be hard-coded. In an embodiment, pre-heating set point temperature T_{ph} can range from about 35° C. to about 40° C. PID_{ph}. In further alternative embodiments, at least one of the pre-heating set point temperature T_{ph} and PID_{ph} can be manually adjusted in real-time by the operator during the pre-heating stage.

FIG. **30** illustrates one exemplary embodiment of the measured cushion temperature T_c (dot-dash-dot line) and power P delivered to the one or more heating cushions **116**, **118**, **1250**, **1650**, **1750** (dot-dot-dash line) with time during the pre-heating stage. Discussed above, the pre-heating stage commences in operation **2010**. Assuming that the pre-heating stage follows the self-test operation preformed in method **2000**, the measured heating cushion temperature is about equal to room temperature T_{RT}. That is, no heat is output by the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** and the heating power P is zero. As shown, room temperature T_{RT} is less than the pre-heating set point temperature T_{ph}. Thus, T_c=T_{ph} is NO and the controller **104** transmits command signal(s) **2012***s* operative to cause the heating power P to increase and the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** generate heat. As shown, the heating power P can rise from zero to a constant value. In response to the heat generation, the measured cushion temperature T_c rises. Once the measured cushion temperature T_c reaches the pre-heating set point temperature T_{ph}, T_c=T_{ph} is YES, and the controller **104** further generates command signal(s) operative to maintain the cushion temperature T_c about equal to the pre-heating set point temperature T_{ph}. As shown, the heating power can remain constant during the pre-heating stage. However, in alternative embodiments, the heating power can increase or decrease as commanded by the controller **104** to achieve the pre-heating set point temperature T_{ph}.

In operation **2014**, the enclosed biological substance **602** is received within the selected dry thawing chamber **200**. As an example, the chamber door **302**, **809**, **811**, **909**, **911**, **1204** is opened to allow placement of the enclosed biological substance **602** within the chamber frame **202**, **1222**, **1224**. In certain embodiments, the enclosed biological substance **602** can be within the overwrap bag **120**, **606**, **1000**, **1100** and the overwrap bag **120**, **606**, **1000**, **1100** can be placed within the chamber frame **202**, **1222**, **1224**.

As shown in FIG. **26**, the user interface **822** can be configured to display an interface **2600** configured to allow input of selected information regarding the enclosed biological substance **602**. Alternatively or additionally, an operator can employ the input device **824** (e.g., a barcode reader configured to read a barcode on the enclosed biological substance **122**, **602**, an RFID reader configured to receive information stored by the RFID tag **1001**, etc.) to automatically enter this information. Examples of information regarding the enclosed biological substance **122**, **602** can include information according to the ISBT 128 standard. Examples include donation identification, product code, and classification of the enclosed biological substance **122**, **602** under the ABO and/or RhD blood group system (ABO/RhD). The donation identification can be a unique identifier for the enclosed biological substance **122**, **602**. The product code can specify physical parameters of the enclosed biological substance **122**, **602**, such as volume. Further information can include an operator name and an expiration date/time.

In operation **2016**, the controller **104** determines whether the chamber door **302**, **809**, **811**, **909**, **911**, **1204** is closed (Door Closed?). In certain embodiments, the chamber door **302**, **809**, **811**, **909**, **911**, **1204** can be in communication with a door sensor (not shown) configured to output a signal in response to opening and closing of the chamber door **302**, **809**, **811**, **909**, **911**, **1204**. Examples of the sensor can include mechanical sensors (e.g., buttons), electromagnetic sensors (e.g., proximity sensors), and the like. The controller **104** can be in signal communication with the door sensor. Upon receipt of an open door signal, the controller **104** can command the user interface **822** to provide an annunciation (e.g., a sound, visual cue, prompt, etc.) to remind the operator to confirm that the chamber door **302**, **809**, **811**, **909**, **911**, **1204** is closed. Alternatively, the controller **104** can refrain from displaying such a prompt under circumstances where a closed door signal is received within a predetermined time after receipt of the open door signal.

An affirmative input by the operator to the annunciation and/or subsequent receipt of the closed door signal can be interpreted by the controller **104** as Door Closed=YES. A negative input or the absence of input to the annunciation can be interpreted by the controller **104** as Door Closed=NO. Once the controller **104** determines that Door Closed=YES, the method **2000** moves to operation **2020**.

In operation **2020**, the controller **104** receives a measurement of the weight W of the enclosed biological substance **122**, **602** from the weight sensor **1279** or a memory. If the controller **104** determines W>0 is NO, the method **2000** returns to the loading operation of operation **2014**. If the controller **104** determines that W>0 is YES, the method **2000** moves to operation **2102** of method **2100**.

Beneficially, the sequence of operations **2014**-**2020** confirms that an enclosed biological substance **122**, **602** is

received within the chamber frame **202**, **1222**, **1224** and that the chamber door **302**, **809**, **811**, **909**, **911**, **1204** is closed. In one aspect, if no enclosed biological substance **122**, **602** is present within the chamber frame **202**, there is no purpose to exiting the pre-heating stage (moving to operation **2102** of method **2100**). In another aspect, if the chamber door **302**, **809**, **811**, **909**, **911**, **1204** is not closed, significant heat may escape from the dry thawing system **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900**, inhibiting the achievement of substantially uniform heating of the enclosed biological substance **122**, **602** and the pre-heating set point temperature T_{ph}.

FIG. **21** is a flow diagram illustrating one exemplary embodiment of a method **2100**, including operations **2102**-**2124**, for determining heating parameters for the enclosed biological substance **122**, **602** during the ice stage based upon measured weight. As discussed above, embodiments of the dry thawing system **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900** can be configured to receive enclosed biological substances **122**, **602** having different volume. It can be appreciated that, if the same heating parameters are employed for significantly different volumes of the enclosed biological substance **122**, **602**, the amount of time required to complete the thawing process (e.g., the ice stage and the liquid stage) can vary significantly. Thus, it can be beneficial to employ different heating parameters based upon the weight of the enclosed biological substance **122**, **602**. Examples of the heating parameters can include a first cushion set point temperature $T_{ci,1}$ within the ice stage, PID settings within the ice stage, and a transition set point temperature T_i between the ice stage and the liquid stage. In this context, the index i ranges from 1 to 4, representing four predefined weight ranges. However, alternative embodiments of the method can include greater or fewer weight ranges and the endpoints of the ranges can be varied as necessary. For example, the weights can be selected between any two desired endpoints (e.g., between about 0 g and about 500 g).

In operation **2102**, the controller **104** determines if the weight W of the enclosed biological substance **122**, **602** is greater than about a predetermined first weight W_1 and less than or equal to about a predetermined second weight W_2 ($W_1<W\leq W_2$?). If $W_1<W\leq W_2$ is YES, the method **2100** moves to operation **2104**, where the heating parameters $T_{ci,1}=T_{c1,1}$, $T_i=T_1$, and $PID_i=PID_1$ are retrieved from memory by the controller **104**. If $W_1<W\leq W_2$ is NO, the method **2100** moves to operation **2106**.

In operation **2106**, the controller **104** determines if the weight W of the enclosed biological substance **122**, **602** is greater than about the predetermined second weight W_2 and less than or equal to about a predetermined third weight W_3 ($W_2<W\leq W_3$?). If $W_2<W\leq W_3$ is YES, the method **2100** moves to operation **2110**, where the heating parameters $T_{ci,1}=T_{c2,i}$, $T_i=T_2$, and $PID_i=PID_2$ are retrieved from memory by the controller **104**. If $W_2<W\leq W_3$ is NO, the method **2100** moves to operation **2112**.

In operation **2112**, the controller **104** determines if the weight W of the enclosed biological substance **122**, **602** is greater than the third predetermined weight W_3 and less than or equal to about a predetermined fourth weight W_4 ($W_3<W\leq W_4$?). If $W_3<W\leq W_4$ is YES, the method **2100** moves to operation **2114**, where the heating parameters $T_{ci,1}=T_{c3,1}$, $T_i=T_3$, and $PID_i=PID_3$ are retrieved from memory by the controller **104**. If $W_3<W\leq W_4$ is NO, the method **2100** moves to operation **2116**.

In operation **2116**, the controller **104** determines if the weight W of the enclosed biological substance **122**, **602** is greater than the fourth predetermined weight W_4 and less than or equal to about a predetermined fifth weight W_5 ($W_4<W\leq W_5$?). If $W_4<W\leq W_5$ is YES, the method **2100** moves to operation **2120**, where the heating parameters $T_{ci,1}=T_{c4,1}$, $T_i=T_4$, and $PID_i=PID_4$ are retrieved from memory by the controller **104**. If $W_4<W\leq W_5$ is NO, the method **2100** moves to operation **2122**.

In operation **2122**, the user interface **822** displays a warning. Display of the warning in operation **2122** can reflect an enclosed biological substance **122**, **602** having a weight that does not fall within the ranges outlined above. Following display of the warning in operation **2122**, the method **2100** can move to operation **2124**, where the user interface **822** displays the measured weight W of the enclosed biological substance **122**, **602** and requests operator input of the parameters $T_{ci,1}$, T_i, and PID_i.

Exemplary embodiments of weight ranges are outlined in Table 1.

TABLE 1

Weight ranges

Index, i	Weight range
1	100 g < W ≤ 200 g
2	200 g < W ≤ 300 g
3	300 g < W ≤ 400 g
4	400 g < W ≤ 500 g

FIG. **22** is a flow diagram illustrating one exemplary embodiment of a method **2200**, including operations **2202**-**2216** for heating the enclosed biological substance **122**, **602** during the ice stage and liquid stage. The ice stage commences in operation **2202** and ends after completion of operation **2210**, while the liquid stage commences in operation **2212** and ends after completion of operation **2214**. In general, the ice stage represents a condition of the enclosed biological substance **122**, **602** in which a predetermined fraction of the enclosed biological substance **122**, **602** is solid (e.g., frozen). The liquid stage represents a condition of the enclosed biological substance **122**, **602** in which a predetermined fraction of the enclosed biological substance **122**, **602** is liquid (e.g., thawed).

In operation **2202**, the controller **104** obtains the ice stage parameters $T_{ci,1}$, T_i, and PID_i. As an example, Table 1 can be a lookup table stored in memory and the ice stage parameters can be determined by the controller **104** from this lookup table based upon the weight of the enclosed biological substance **122**, **602**.

In operation **2204**, the controller **104** generates one or more command signals **2204***s* operative to control power delivered to the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** to effect the temperature of respective heating cushions **116**, **118**, **1250**, **1650**, **1750**. As discussed above, the controller **104** is configured to perform closed-loop control of the heating cushion temperature.

In order to generate the command signals **2204***s*, the controller **104** determines if there is a difference between each measured cushion temperature T_c and the first cushion set point temperature $T_{ci,1}$ ($T_c=T_{ci,1}$?). As illustrated in Table 1, the first cushion set point temperature $T_{ci,1}$ can range from about 37° C. to about 42° C., based upon the weight W of the enclosed biological substance **122**, **602**. If the controller **104** determines that there is a difference between the measured cushion temperature T_c and the first cushion set point temperature $T_{ci,1}$ ($T_c=T_{ci,1}$ is NO), a correction is calculated based upon this difference and PID_i. The correction is transmitted from the controller **104** to respective ones of the heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** as

the command signals **2204***s* and the method **2200** returns to operation **2202**. In operation **2202**, the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** generate heat in response to receipt of the command signal(s) **2204***s*. Subsequently, the method **2200** moves to operation **2204** to again determine if there is a difference between each measured cushion temperature T_c and the first cushion set point temperature $T_{ci,1}$. The operations **2202** and **2204** are repeated in sequence until the measured cushion temperature T_c is about equal to the first cushion set point temperature $T_{ci,1}$ (T_c=$T_{ci,1}$ is YES). Subsequently, the method **2200** can move to operation **2206**.

In operation **2206**, the controller **104** determines whether the measured temperature T_b of the enclosed biological substance **122**, **602** is equal to the transition set point temperature T_i (T_b=T_i?). In an embodiment, the transition set point temperature T_i can be a temperature above 0° C. at which most or all of the enclosed biological substance **122**, **602** is melted into liquid. As illustrated in Table 1, the transition set point temperature T_i can range from about 5° C. to about 8° C. If T_b=T_i is NO in operation **2206**, the method **2200** returns to operation **2202**. Alternatively, when T_b=T_i is YES in operation **2206**, the method **2200** moves to operation **2210**, which ends the ice stage and begins the liquid stage.

FIG. **30** illustrates one exemplary embodiment of the measured cushion temperature T_c (dot-dash-dot line), the measured temperature T_b, of the enclosed biological substance **122**, **602** and power P delivered to the one or more heating cushions **116**, **118**, **1250**, **1650**, **1750** (dot-dot-dash line) as a function of time during the ice stage. Assuming that the ice stage follows the pre-heating stage, at thawing time t=0, the measured cushion temperature T_c is about the pre-heating set point temperature T_{ph} and the measured temperature T_b of the enclosed biological substance **122**, **602** is at an initial temperature T_o. The initial temperature T_o can be a temperature at which the enclosed biological substance **122**, **602** is stored in its frozen state.

When transitioning from the pre-heating stage to the ice stage, the set point temperature for the heating cushion changes from the pre-heating set point temperature T_{ph} to the first cushion set point temperature $T_{ci,1}$. As shown in FIG. **30**, the first cushion set point temperature $T_{ci,1}$ is greater than the pre-heating set point temperature T_{ph}. Thus, T_c=$T_{ci,1}$ is NO in operation **2204** and the controller **104** transmits command signal(s) **2204***s* operative to cause the heating power P to increase and the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** generate more heat. As shown, the heating power P can rise from the pre-heating stage power P_{ph} at thawing time t=0 to an ice stage power level Pi.

In response to the increased heat generation during the ice stage, the measured cushion temperature T_c rises. Once the measured cushion temperature T_c reaches the first cushion set point temperature $T_{ci,1}$ (T_c=$T_{ci,1}$ is YES in operation **2204**), the controller **104** further generates command signal(s) operative to maintain the cushion temperature T_c about equal to the first cushion set point temperature $T_{ci,1}$. As shown, the heating power can remain about constant during the ice stage. However, in alternative embodiments, the heating power P can increase or decrease as commanded by the controller to achieve the first cushion set point temperature $T_{ci,1}$.

Concurrently, the measured temperature T_b of the enclosed biological substance **122**, **602** initially rises from T_o at thawing time t=0. With increasing time, the measured temperature T_b of the enclosed biological substance **122**, **602** increases until it reaches its melting point. Subsequently, the heat generated by the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** is employed for melting, that is, a solid to liquid phase transition. While this phase transition occurs, the measured temperature T_b of the enclosed biological substance **122**, **602** remains approximately constant. Once at least a portion of the enclosed biological substance **122**, **602** becomes liquid, the measured temperature T_b of the enclosed biological substance **122**, **602** begins to increase again. The ice stage continues until the measured temperature T_b of the enclosed biological substance **122**, **602** is about equal to the transition set point temperature T_i (T_b=T_i is YES in operation **2206**).

The liquid stage begins in operation **2210** of method **2200**. In operation **2210**, the controller **104** obtains the following liquid stage parameters: a second cushion set point temperature $T_{c,L}$, a final set point temperature T_f, and liquid stage PID settings PID_L. The liquid stage parameters $T_{c,L}$, T_f, and PID_L can be independently received by the controller **104** in a variety of ways. In one aspect, these parameters can be input by the operator via the user interface **822**. In another aspect, these liquid stage parameters can be retrieved from a memory. In a further aspect, these liquid stage parameters can be hard-coded. In certain embodiments, $T_{c,L}$ can be selected from about 35° C. to about 36° C. (e.g., about 36° C.).

In operation **2212**, the controller **104** generates one or more command signals **2212***s* operative to control power delivered to the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** to effect the temperature of respective heating cushions **116**, **118**, **1250**, **1650**, **1750**. As discussed above, the controller **104** is configured to perform closed-loop control of the heating cushion temperature.

In order to generate the command signals **2212***s*, the controller **104** determines if there is a difference between each measured cushion temperature T_c and the second cushion set point temperature $T_{c,L}$ (T_c=$T_{c,L}$?). If the controller **104** determines that there is a difference between the measured cushion temperature T_c and the second cushion set point temperature $T_{c,L}$ (T_c=$T_{c,L}$ is NO), a correction is calculated based upon this difference and PID_L. The correction is transmitted from the controller **104** to respective ones of the heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** as the command signals **2212***s* and the method **2200** returns to operation **2202**. In operation **2210**, the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** generate heat in response to receipt of the command signal(s) **2212***s*. Subsequently, the method **2200** moves to operation **2012** to again determine if there is a difference between each measured cushion temperature T_c and the first cushion set point temperature $T_{c,L}$. The operations **2210** and **2212** are repeated in sequence until the measured cushion temperature T_c is about equal to the second cushion set point temperature $T_{c,L}$ (T_c=$T_{c,L}$ is YES). Subsequently, the method **2200** can move to operation **2214**.

In operation **2214**, the controller **104** determines whether the measured temperature T_b of the enclosed biological substance **122**, **602** is equal to the predetermined final set point temperature T_f (T_b=T_f ?). The final set point temperature T_f can represent a target temperature for the liquid stage. That is, a temperature sufficiently high to ensure that all of the enclosed biological substance **122**, **602** is thawed (e.g., in the liquid phase) but not so high that the enclosed biological substance **122**, **602** is thermally damaged. If T_b=T_f is NO in operation **2214**, the method **2200** returns to operation **2210**, where the controller **104** continues to command the one or more heating assemblies **108**, **110**, **400**, **500**,

1208, **1242**, **1732** to generate heat. If T_b=T_f is YES in operation **2214**, the method **2200** moves to operation **2216**, which ends the liquid stage and begins the standby stage.

In general, the final set point temperature T_f can range from about 0° C. to about 37° C. the exact value of the final set point temperature T_f can be dependent upon the type of enclosed biological substance and/or the weight of the enclosed biological substance. In an embodiment where the enclosed biological substance is a blood plasma, the final set point temperature T_f can range from about 30° C. to about 37° C. (e.g., about 33.5° C.). In an embodiment, the enclosed biological substance **122**, **602** can be a blood component and the value of the final set point temperature T_f can be based upon the blood component according to standards set by regional, national, and/or international standard bodies. In one embodiment, T_f can be determined pursuant to the "Circular of Information for the Use of Human Blood and Blood Components," published by AABB, November 2017.

Referring again to FIG. **30**, the measured temperature of the heating cushion T_c, the measured temperature T_b of the enclosed biological substance **122**, **602**, and power P delivered to the one or more heating cushions **116**, **118**, **1250**, **1650**, **1750** (dot-dot-dash line) as a function of time are also illustrated in the liquid stage. As shown, the liquid stage follows the ice stage. At thawing time t=t_1, the measured cushion temperature T_c is about equal to the first cushion set point temperature $T_{ci,1}$ and the measured temperature T_b of the enclosed biological substance **122**, **602** is about equal to the transition set point temperature T_i.

When transitioning from the ice stage to the liquid stage, the set point temperature for the heating cushion changes from the first set point temperature $T_{ci,1}$ to the second cushion set point temperature $T_{c,L}$. As shown in FIG. **30**, the second cushion set point temperature $T_{c,L}$ is less than the first cushion set point temperature $T_{ci,1}$. Thus, T_c=$T_{c,L}$ is NO in operation **2212** and the controller **104** transmits command signal(s) **2204***s* operative to cause the heating power P to decrease. That is, the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** generate less heat at the start of the liquid stage, as compared to the end of the ice stage, in order to decrease the measured heating cushion temperature T_c. As shown, the heating power P can decrease from the ice stage power Pi at thawing time t=t_1.

In response to the reduction in heat generated by the heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732**, the measured cushion temperature T_c decreases. Once the measured cushion temperature T_c reaches the second cushion set point temperature $T_{c,L}$ (T_c=$T_{c,L}$ is YES in operation **2212**), the controller **104** further generates command signal(s) operative to maintain the cushion temperature T_c about equal to the second cushion set point temperature $T_{c,L}$. As shown, the heating power P can decrease throughout the duration of the liquid stage. However, in alternative embodiments, the heating power P can increase or decrease as commanded by the controller **104** to achieve the second cushion set point temperature $T_{c,L}$.

Concurrently, the measured temperature T_b of the enclosed biological substance **122**, **602** rises relatively rapidly from T_i at thawing time t=t_1. However, with increasing time, the slope of the temperature-time response the measured temperature T_b of the enclosed biological substance **122**, **602** decreases. The liquid stage continues until the measured temperature T_b of the enclosed biological substance **122**, **602** is about equal to the final set point temperature T_f (T_b=T_f is YES in operation **2214**).

With the conclusion of the liquid stage in operation **2214**, the method **2200** enters the standby stage when moving to operation **2216**. In operation **2216**, the controller **104** obtains the following standby stage parameters: a third cushion set point temperature $T_{c,SB}$ and standby stage PID settings PID_{SB}. The standby stage parameters $T_{c,SB}$ and PID_{SB} can be independently received by the controller **104** in a variety of ways. In one aspect, the standby stage parameters can be input by the operator via the user interface **822**. In another aspect, the standby stage parameters can be retrieved from a memory. In a further aspect, the standby stage parameters can be hard-coded. In certain embodiments, the third cushion set point temperature $T_{c,SB}$ can be selected from about 35° C. to about 37° C. (e.g., about 35° C.)

During the standby stage of operation **2216**, the controller **104** is further configured to maintain the temperature of the one or more heating cushions **116**, **118**, **1250**, **1650**, **1750** to be about equal to the third cushion set point temperature $T_{c,SB}$. Similar to the discussion above, in operation **2216**, the controller **104** can generate standby command signals operative to control power delivered to the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** in order to maintain the cushion temperature about equal to the standby set point temperature $T_{c,SB}$. The standby command signals can be based upon the PID_{SB} and the difference between the measured cushion temperature T_c and the fourth cushion set point temperature $T_{c,SB}$.

When transitioning from the liquid stage, the set point temperature for the heating cushion changes from the second set point temperature $T_{c,L}$ to the third cushion set point temperature $T_{c,SB}$. However, as shown in FIG. **30**, the third cushion set point temperature $T_{c,SB}$ can be about equal to the second cushion set point temperature $T_{c,L}$. Furthermore, the heating power P can continue to decrease during the standby stage. Concurrently, the measured temperature of the enclosed biological substance **122**, **602** can be about constant during the standby stage.

Embodiments of the controller **104** can also be configured to record the elapsed time of the ice stage, the liquid stage, and the standby stage. As discussed below, in certain embodiments, the controller **104** can also be configured to halt the thawing process during the method **2200** based upon measurements of elapsed time.

As illustrated in FIG. **23**, in operation **2302**, the controller **104** zeros a thawing time t maintained by a thawing timer after the pre-heating is completed and prior to the ice stage. In operation **2304**, when the ice stage commences at operation **2202**, the thawing timer is started.

In operation **2306**, while the thawing timer is running, the controller **104** determines if the thawing time t exceeds a maximum thawing time t_{max} (t>t_{max} ?). In general, the maximum thawing time t_{max} represents a predetermined safe time duration for thawing of the enclosed biological substance **122**, **602**. Therefore, if t>t_{max} is YES, the method **2300** moves to operation **2310**, entering a timeout condition. In the timeout condition, the controller **104** commands the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732** to stop generating heat and generates a message for display by the user interface **822** indicating the timeout condition and prompting the operator to remove the enclosed biological substance **122**, **602** from the dry thawing **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900** for disposal. Alternatively, if t>t_{max} is NO, the method **2300** moves to operation **2312**.

In operation **2312**, the controller **104** determines when the liquid stage has ended. Similar to operation **2214**, the controller **104** determines the end of the liquid stage when the measured temperature T_b of the enclosed biological substance **122**, **602** is equal to a the final set point tempera-

ture T_f (T_b=T_f?). If T_b=T_f is NO, the method **2300** returns to operation **2306**. If T_b=T_f is YES, the method **2300** moves to operation **2214**.

In operation **2314**, the controller **104** records a first thawing time t_1 elapsed for the ice stage, a second thawing time t_2 elapsed for the liquid stage, and a total thawing time t_t given by the sum of the first and second thawing times t_1, t_2. The thawing time t_1 is determined from the start of operation **2202** to when T_b=T_i is YES in operation **2206**. The thawing time t_2 is determined from the ice stage time t_1 to when T_b=T_f is YES in operation **2214**. Subsequently, the method **2300** moves to operation **2316**.

In operations **2316-2324**, the controller **104** monitors an amount of standby time t_{sb} elapsed during the standby stage. In general, it can be desirable for the enclosed biological substance **122**, **602** to be removed from the dry thawing **100***a*, **100***b*, **100***c*, **100***d*, **800**, **900** shortly after the liquid stage is complete. Accordingly, the controller **104** can alert the operator when the standby time t_{sb} exceeds a predetermined maximum standby time t_{sb}, In operation **2316**, the controller **104** zeros the standby timer t_{sb}. In operation **2320**, the controller **104** starts a standby timer to record the standby time t_{sb}.

In operation **2322**, the controller **104** determines whether the standby time t_{sb} equals the maximum standby time t_{sb}, max (t_{sb}=$t_{sb,\ max}$?). If t_{sb}=$t_{sb,\ max}$ is NO, the method **2300** returns to **2322** and the standby timer t_{sb} continues running. If t_{sb}=$t_{sb,\ max}$ is YES, the method **2300** moves to operation **2324**.

In operation **2324**, the controller **104** generates a notification to alert the operator that the maximum standby time t_{sb}, max has been reached. The notification can include any audio and/or visual signal. Examples can include audible alarms, lights, and messages displayed by the user interface **822**.

Subsequently, in operation **2326**, the user interface **822** can display the current temperature T_b of the enclosed biological substance **122**, **602**, the total thawing time t_t (t_1+t_2), and the standby time t_{sb}. The controller **104** can further return to the operation **2010** of method **2100** to prepare the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** for receipt of another enclosed biological substance **122**, **602**.

FIG. **27** illustrates an embodiment of an interface **2700** displayed by the user interface **822** during the ice stage and the liquid stage. As shown, the measured temperature t_b of the enclosed biological substance **122**, **602** (e.g., 20° C.) is displayed, as well as thawing time t elapsed from commencement of the ice stage at thawing time t=0. In certain embodiments, the first thawing time t_1 at which the transition between the ice stage and the liquid stage occurs. An indicator light **2704** of the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** (e.g., Chamber A) can also display a first color representing the status of the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** as in use (e.g., an orange color). Alternatively or additionally, in further embodiments, the first color can be displayed by the user interface **822**.

FIG. **28** illustrates an interface **2800** displayed by the user interface **822** upon completion of the dry thawing process (e.g., operation **2326** of method **2300**). As shown, the measured temperature t_b of the enclosed biological substance **122**, **602** is displayed (e.g., 37° C.), as well as the total time t_t elapsed in the dry thawing process and the standby time t_{sb}. The indicator light **2704** of the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** can also display a second color representing the status of the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** as complete (e.g., a green color). Alternatively or additionally, in further embodiments, the second color can be displayed by the user interface **822**.

As illustrated in FIG. **29** the operator can select a "stop" option from an interface **2900** displayed by the user interface **822**. The "stop" option can be selected at any time during the pre-heating stage, the ice stage, the liquid stage, or the standby stage. Selection of the "stop" option during any of the pre-heating stage, the ice stage, the liquid stage, and the standby stage aborts the thawing and/or heating process and causes the controller **104** to cut power to the one or more heating assemblies **108**, **110**, **400**, **500**, **1208**, **1242**, **1732**. Selection of the "stop" option during the standby stage indicates that the dry thawing process has been completed and the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** is available to receive another frozen biological substance. Following selection of the "stop" option during the standby stage, the controller **104** can return to the operation **2010** of method **2100** to prepare the selected dry thawing chamber **200**, **804**, **800**, **904**, **906** for receipt of another enclosed biological substance **122**, **602**.

The terms and expressions which have been employed herein are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed. Thus, it should be understood that although the present invention has been specifically disclosed by preferred embodiments, exemplary embodiments and optional features, modification and variation of the concepts herein disclosed may be resorted to by those skilled in the art, and that such modifications and variations are considered to be within the scope of this invention as defined by the appended claims. The specific embodiments provided herein are examples of useful embodiments of the present invention and it will be apparent to one skilled in the art that the present invention may be carried out using a large number of variations of the devices, device components, methods steps set forth in the present description. As will be obvious to one of skill in the art, methods and devices useful for the present methods can include a large number of optional composition and processing elements and steps.

Values or ranges may be expressed herein as "about" and/or from/of "about" one particular value to another particular value. When such values or ranges are expressed, other embodiments disclosed include the specific value recited and/or from/of the one particular value to another particular value. Similarly, when values are expressed as approximations, by the use of antecedent "about," it will be understood that here are a number of values disclosed therein, and that the particular value forms another embodiment. It will be further understood that there are a number of values disclosed therein, and that each value is also herein disclosed as "about" that particular value in addition to the value itself. In embodiments, "about" can be used to mean, for example, within 10% of the recited value, within 5% of the recited value or within 2% of the recited value.

Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described. Nothing

herein is to be construed as an admission that the invention is not entitled to antedate such disclosure by virtue of prior invention.

For purposes of describing and defining the present teachings, it is noted that unless indicated otherwise, the term "substantially" is utilized herein to represent the inherent degree of uncertainty that may be attributed to any quantitative comparison, value, measurement, or other representation. The term "substantially" is also utilized herein to represent the degree by which a quantitative representation may vary from a stated reference without resulting in a change in the basic function of the subject matter at issue.

One skilled in the art will appreciate further features and advantages of the invention based on the above-described embodiments. Accordingly, the invention is not to be limited by what has been particularly shown and described, except as indicated by the appended claims. All publications and references cited herein are expressly incorporated herein by reference in their entirety. Any patent, publication, or information, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated material does not conflict with existing definitions, statements, or other disclosure material set forth in this document. As such the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference.

What is claimed is:

1. A method for thawing a biological substance, the method comprising:

pivoting a first chamber door on a first side of a housing from a closed position to an open position to provide access to a first cavity within the housing;

positioning a first enclosed biological substance in a frozen state into the first cavity in the housing;

pivoting the first chamber door to the closed position to cause a first heating assembly mounted on the first chamber door to contact the first enclosed biological substance;

activating the first heating assembly to cause a first heater of the first heating assembly to generate thermal energy to heat the first enclosed biological substance from the frozen state to a fluid state through conduction of heat from the first heating assembly to the first enclosed biological substance; and

pivoting a second heating assembly relative to the first heating assembly to agitate the first enclosed biological substance.

2. The method of claim **1**, wherein, when the first chamber door is moved to the closed position, the first enclosed biological substance is engaged between the first heating assembly on the first chamber door and the second heating assembly disposed within the housing.

3. The method of claim **2**, further comprising activating the second heating assembly to cause a second heater of the second heating assembly to generate thermal energy to heat the first enclosed biological substance from the frozen state to a fluid state through conduction of heat from the second heating assembly to the first enclosed biological substance.

4. The method of claim **2**, wherein the second heating assembly is mounted on a first pivoting agitator plate, and wherein pivoting the second heating assembly relative to the first heating assembly comprises activating a first agitation device to cause the first pivoting agitator plate to pivot and thereby agitate the first enclosed biological substance.

5. The method of claim **1**, further comprising monitoring a temperature of at least one of the first heating assembly and the first enclosed biological substance.

6. The method of claim **1**, further comprising pivoting a second chamber door on a second side of a housing from a closed position to an open position to provide access to a second cavity within the housing; and

positioning a second enclosed biological substance in a frozen state into the second cavity in the housing.

7. The method of claim **6**, further comprising activating a third heating assembly mounted on the second chamber door to cause a third heater of the third heating assembly to generate thermal energy to heat the second enclosed biological substance from the frozen state to a fluid state.

8. A method for thawing a biological substance, the method comprising:

providing a dry thawing device comprising a housing, a first chamber frame disposed within the housing, wherein the first chamber frame comprises a first base extending from a first end to a second end, a first chamber door pivotally mounted to the first end of the base and disposed at a first end of the housing, and a first heating assembly mounted on an inner surface of the first chamber door;

pivoting the first chamber door from a closed position to an open position to provide access to a first cavity within the housing;

positioning a first enclosed biological substance in a frozen state into the first cavity;

pivoting the first chamber door to the closed position to cause the first heating assembly to contact the first enclosed biological substance;

activating the first heating assembly to heat the first enclosed biological substance from the frozen state to a fluid state; and

pivoting a second heating assembly relative to the first chamber frame to agitate the first enclosed biological substance.

9. The method of claim **8**, wherein the second heating assembly is disposed within the housing, and wherein the first and second heating assemblies define the first cavity.

10. The method of claim **9**, wherein the second heating assembly is mounted on an agitator plate disposed within the housing, wherein the agitator plate is pivotally connected to the first chamber frame, and wherein pivoting the second heating element comprises pivoting the agitator plate about a pivot axis to agitate the first enclosed biological substance.

11. The method of claim **10**, wherein the agitator plate is pivotally mounted to a support that is linearly slidably mounted on the base of the first chamber frame.

12. The method of claim **8** further comprising measuring a temperature of at least one of the first heating assembly, the second heating assembly, and the first enclosed biological substance within the first cavity.

13. The method of claim **8** further comprising measuring a weight of the first enclosed biological substance within the first cavity.

14. The method of claim **8** further comprising placing the first enclosed biological substance into an overwrap bag before positioning the first enclosed biological substance into the first cavity.

15. The method of claim **8**, wherein the dry thawing device further comprises:

a second chamber frame disposed within the housing, wherein the second chamber frame comprises a second base extending from a first end to a second end; and

a second chamber door pivotally mounted to the first end of the second base and disposed at a second end of the housing opposite the first end.

16. The method of claim 9, wherein the dry thawing device further comprises:

a second chamber frame disposed within the housing, wherein the second chamber frame comprises a second base extending from a first end to a second end;

a second chamber door pivotally mounted to the first end of the second base and disposed at a second end of the housing opposite the first end; and

a third heating assembly mounted on an inner surface of the second chamber door.

17. The method of claim 16 further comprising:

pivoting the second chamber door from a closed position to an open position to provide access to a second cavity within the housing;

positioning a second enclosed biological substance in a frozen state into the second cavity in the housing;

pivoting the second chamber door to the closed position to cause the third heating assembly to contact the second enclosed biological substance; and

activating the third heating assembly to heat the second enclosed biological substance from the frozen state to a fluid state.

18. A method for thawing a biological substance, the method comprising:

providing a dry thawing device comprising:

a housing having opposed top and bottom sides, opposed front and back sides extending between the top and bottom sides, and opposed left and right sides extending between the top and bottom sides and between the front and back sides; and

a first chamber door positioned on the left side of the housing and comprising a first heating assembly mounted thereon;

pivoting the first chamber door from a closed position to an open position to provide access to a first cavity within the housing;

positioning a first enclosed biological substance in a frozen state into the first cavity in the housing;

pivoting the first chamber door to the closed position to cause the first heating assembly to contact the first enclosed biological substance;

activating the first heating assembly to heat the first enclosed biological substance from the frozen state to a fluid state via conduction; and

pivoting a second heating assembly relative to the first heating assembly to agitate the first enclosed biological substance.

19. The method of claim 18, wherein the dry thawing device further comprises a second chamber door positioned on the right side of the housing, wherein the second chamber door comprises a third heating assembly mounted thereon, the method further comprising:

pivoting the second chamber door from a closed position to an open position to provide access to a second cavity within the housing;

positioning a second enclosed biological substance in a frozen state into the second cavity;

pivoting the second chamber door to the closed position to cause the third heating assembly to contact the second enclosed biological substance; and

activating the third heating assembly to heat the second enclosed biological substance from the frozen state to a fluid state.

20. The method of claim 19, wherein the first and second chamber doors are mounted adjacent to the bottom side of the housing such that an upper portion of each of the first and second chamber doors moves away from the top side of the housing when pivoting each of the first and second chamber doors from the closed position to the open position.

21. The method of claim 1, wherein the first heating assembly comprises a fluid-filled cushion positioned between the first heater and the first enclosed biological substance, and wherein heat is transferred from the first heater to the first enclosed biological substance through the fluid-filled cushion via conduction.

22. The method of claim 8, wherein heat is transferred from the first heating assembly to the first enclosed biological substance via conduction.

23. The method of claim 22, wherein the first heating assembly comprises a first heater, and wherein activating the first heating assembly comprises transferring heat from the first heater to the first enclosed biological substance via conduction.

24. The method of claim 23, wherein the first heating assembly further comprises a fluid-filled cushion positioned between the first heater and the first enclosed biological substance, and wherein heat is transferred from the first heater to the first enclosed biological substance through the fluid-filled cushion via conduction.

25. The method of claim 18, wherein the first heating assembly comprises a first heater, and wherein activating the first heating assembly comprises transferring heat from the first heater to the first enclosed biological substance via conduction.

26. The method of claim 25, wherein the first heating assembly further comprises a fluid-filled cushion positioned between the first heater and the first enclosed biological substance, and wherein heat is transferred from the first heater to the first enclosed biological substance through the fluid-filled cushion via conduction.

27. The method of claim 1, wherein pivoting the second heating assembly comprises rotating a cam.

28. The method of claim 1, wherein pivoting the second heating assembly comprises pivoting the second heating assembly while the first heating assembly is stationary.

29. The method of claim 1, further comprising linearly sliding the second heating assembly.

30. The method of claim 29, further comprising linearly sliding a first edge of an agitator plate, upon which the second heating assembly is mounted, along a track, and wherein a second edge of the agitator plate opposite the first edge of the agitator plate is pivotably mounted to a support.

31. The method of claim 1, wherein pivoting the second heating assembly relative to the first heating assembly alternatingly applies a compressive force to the first enclosed biological substance.

32. The method of claim 6, further comprising:

activating a third heating assembly mounted on the second chamber door to cause a third heater of the third heating assembly to generate thermal energy to heat the second enclosed biological substance from the frozen state to a fluid state; and

pivoting a fourth heating assembly relative to the third heating assembly to agitate the second enclosed biological substance.

33. The method of claim 17, further comprising:

activating a third heating assembly mounted on the second chamber door to cause a third heater of the third heating assembly to generate thermal energy to heat the second enclosed biological substance from the frozen state to a fluid state; and

pivoting a fourth heating assembly relative to the third heating assembly to agitate the second enclosed biological substance.

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